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CHARLES WARDELL STILES
1867–1941

The death on January 24, 1941, of Dr. Charles Wardell Stiles, retired medical director of the United States Public Health Service and for 30 years chief of the Division of Zoology of the National Institute of Health (formerly the Hygienic Laboratory), marked the passing of a pioneer American zoologist and virtually the end of an epoch in American parasitology.*

Dr. Stiles was born at Spring Valley, N. Y., on May 15, 1867, the son of Rev. Samuel Martin and Elizabeth White Stiles. Part of his undergraduate work was taken at Wesleyan University but in 1886 he enrolled in the Collège de France and later attended the University of Berlin. He obtained his A.M. and Ph.D. degrees at Leipzig. The year 1891 found him at the Trieste Zoological Station and later at the Pasteur Institute. On his return to the United States later in that year he was appointed to the position of Zoologist in the United States Bureau of Animal Industry, where, along with Curtice and Hassall, he laid the foundations for the zoological work of that Bureau and participated in the outstanding achievements which marked its progress.

One of Dr. Stiles' first assignments in the Bureau of Animal Industry was to compile a report on the animal parasites of cattle. In preparing the material on cestodes, so many contradictions in the diagnoses of species were encountered that he found it necessary to restudy the whole group, a study which resulted in the publication in 1893 by Stiles and Hassall of the bulletin entitled "A revision of the adult cestodes of cattle, sheep and allied animals." It has been said that Stiles evinced little interest in the subject of zoological nomenclature until his election to the secretaryship of the International Commission. However, in his first major publication he discussed at some length the question of nomenclature in relation to his problem and observed that "the only way to establish an international nomenclature in medical zoology, as well as in other branches of biology, is to enforce the law of priority." The foresight and soundness of the

* An excellent portrait of Dr. Stiles was published in this JOURNAL in June, 1933 (19: 257), accompanying an article by Benjamin Schwartz entitled "A Brief Resume of Dr. Stiles' Contribution to Parasitology." In the August, 1939, issue appeared Dr. Stiles' reminiscent "Early History, in Part Esoteric, of the Hookworm (Uncinariasis) Campaign in our Southern United States."

work in this bulletin are exemplified by some of the conclusions summarized, as follows: (1) Descriptions of cestodes based upon external form alone, unassociated with internal anatomy, are of little value. (2) The present genus *Taenia,* as generally accepted by authors, contains forms which must be restudied and arranged in several sub-families and a number of genera. (3) This revision must be based on internal anatomy. (4) In the adult cestodes of cattle and sheep three genera, *Moniezia,* R. Bl., *Thysanosoma* Dies., and *Stilesia* Rail., are recognized. In this publication, Stiles reported briefly on life history studies with *Moniezia expansa.* While the experiments with the feeding of ova to sheep and the attempts to infect various invertebrate hosts were entirely negative, Stiles predicted that "some insect, worm, or snail will be found to contain the larval stage."

Stiles' bulletin on tapeworms of poultry in 1896 laid down some very specific criteria for cestode life history studies. Suggested methods of investigation were cited, as follows: (1) Experimental infection by feeding known larval stages in invertebrates; (2) experimental infection of invertebrates by feeding ova of bird tapeworms; (3) comparison of hooks on adults with hooks on larval stages; and (4) wild speculation totally devoid of any scientific foundation. Stiles commented: "The less said about the fourth method the better."

Stiles' continued interest in the cestodes was further reflected by the publication in 1896 of "A revision of the adult tapeworms of hares and rabbits." In this bulletin it was noted that none of the adult leporine tapeworms described from Europe had been found in America and that American forms described as *Taenia pectinata* must be distributed over several species. *Anoplocephala, Cittotaenia* and *Davainea* were considered as valid genera with the impression that *Andrya* and *Bertia* would be recognized as valid when sufficient material became available for study.

In his report on the verminous diseases of cattle, sheep and goats in Texas, Dr. Stiles made some very practical contributions to the subject of ruminant parasites. His critical anthelmintic tests were among the first to be conducted on ruminants and the measures which he advocated for the control of strongylid parasites were particularly sound when viewed in the light of our broader present day knowledge. The inefficacy of intratracheal injections for the treatment of lungworm infections was noted; and Stiles in this investigation was apparently the first to carry out experiments on the mechanism of the passage of fluids to the ruminant stomach.

During the years 1898 and 1899, Dr. Stiles served as agricultural attaché to the American Embassy in Berlin and conducted investigations to determine the value of the microscopic inspection of pork for trichinae, to ascertain whether any cases of trichinosis could be traced to American

pork inspected by the United States Department of Agriculture and to investigate the charges brought in Germany against American meats. It will be recalled that in 1880 Germany prohibited the importation of sausage and chopped pork products from the United States and in 1883 excluded all American pork. By the decree of 1891, following the Saratoga Convention, American pork products were readmitted with the understanding that the United States Department of Agriculture should inspect them microscopically for trichinae before shipment. Microscopic inspection was then instituted. However, while the Imperial German Government recognized the certificates of inspection as valid for customs purposes, no agreement was made by which any kingdom, state or local authority was required to recognize the documents for sanitary or health purposes. As a consequence, local restrictions were promulgated which interfered seriously with the flow of American pork into the channels of German trade.

Dr. Stiles' exhaustive investigations and his subsequent voluminous report showed in substance that not a single case of trichinosis in Germany had ever been traced to American certified pork, that claims for the causation of trichinosis by uncertified American pork were either unjustified or could not be substantiated by the evidence, and that the microscopic inspection of pork in Germany was a very costly procedure and led to a false sense of security since cases of the disease were known to have occurred following the ingestion of such pork.

While Dr. Stiles' contributions to veterinary parasitology were of outstanding merit, this earlier work has been overshadowed by his achievements in the field of public health and it is for the latter that he will be most remembered. As a preliminary excursion into this field, while still in the Bureau of Animal Industry, he compiled at the request of Surgeon General Walter Wyman of the United States Public Health Service a report on "The significance of the recent American cases of hookworm disease (uncinariasis, or anchylostomiasis) in man," and a few months later on May 10, 1902, he described for the first time the New World hookworm, *Uncinaria americana,* later renamed by him *Necator americanus.* In his lectures to medical students, Stiles had frequently expressed the view that hookworm disease probably existed in the southern United States, and a statement in the paper in question crystallized this view in the following words:

> "*Uncinaria americana* is known to occur in Texas, in Virginia, and in Puerto Rico, and this wide geographic separation shows very clearly that in the new world we have a special, heretofore undescribed parasite which causes uncinariasis. This further indicates very strongly the correctness of the view that uncinariasis is endemic in the southern states, although it is rarely recognized."

On August 16, 1902, Dr. Stiles was appointed Professor of Zoology in the United States Public Health Service and organized the newly

authorized Division of Zoology in the Hygienic Laboratory. Shortly thereafter, he set out on an investigational tour of the South and on October 24, 1902, published a preliminary report of his findings which indicated in substance that hookworm disease was one of the most important and most common diseases of the South. The report concluded in part with the following prophetic words:

> "All of the cases thus far examined are due to *Uncinaria americana*, demonstrating clearly that this is an endemic infection. . . . There is, in fact, not the slightest room for doubt that uncinariasis is one of the most important and most common diseases of this part of the South, especially on farms and plantations in sandy districts, and indications are not entirely lacking that much of the trouble popularly attributed to 'dirt-eating,' 'resin-chewing,' and even some of the proverbial laziness of the poorer classes of the white population are in reality various manifestations of uncinariasis."

The soundness of this view became increasingly evident as other investigators, notably Dr. H. F. Harris of the Georgia State Board of Health, added confirmation to the findings but it was Dr. Stiles who inspired and motivated the hookworm campaign which followed.

In his contemporary history "Our Times," Mark Sullivan relates very entertainingly how hookworm disease came to be brought forcibly to the attention of the American people. Dr. Stiles had been detailed by Surgeon General Walter Wyman to present before the Pan-American Sanitary Conference held in Washington, D. C., December 4, 1902, a report of his investigational field trip in the South. As the paper was being read, the polysyllabic words seemed to act as a somnifacient on the apathetic cerebrum of a young man slumped in a seat in the front row of the hall. Suddenly, as Dr. Stiles brought out his point that hookworm disease might be the cause of the so-called laziness of the South, the young man's mental faculties sprang to life again and his flying fingers spread penciled words across the pages of a notebook which had almost fallen from his inert hand. The strange reawakening of the young man remained a mystery to Dr. Stiles until the next day when the staring headlines of the New York Sun informed him that he had discovered the "Germ of Laziness."

While the facetious headline and the humorous story carried under its banner created considerable controversy and engendered harsh criticism, particularly in the South, the article no doubt was responsible more than any other one thing for bringing to the attention of the medical profession and the public in general the importance of hookworm disease.

In the face of the criticism which arose like an enveloping cloud, Dr. Stiles carried the hookworm message to the South and persistently pursued an educational campaign designed to convince the medical profession, public health officials and the hookworm victim himself of the seriousness of the situation. He wrote papers, articles and bulletins; lectured before medical groups and other audiences; promoted the es-

tablishment of hookworm clinics; organized hookworm instruction courses in the schools; and did a prodigious amount of spade work in preparing the South for the control campaign which was to follow.

The Act of January 29, 1907, providing for an investigation of woman and child labor in the United States, gave further opportunity for dealing with the problem. Dr. Stiles was detailed to investigate health conditions among cotton mill workers. Studies conducted in 169 mills and establishments in 6 Southern States and 26 mills in 3 New England States disclosed the fact that the so-called "cotton mill anemia" of the South, which had been assumed to be due to the inhalation of cotton lint, was in reality a manifestation of hookworm disease.

In 1908 and 1909, Dr. Stiles cooperated closely with the Country Life Commission appointed by President Theodore Roosevelt and assumed a prominent part in extensive studies in rural sanitation. As an outgrowth of this and Dr. Stiles' other work, Mr. John D. Rockefeller became interested in the problem of hookworm disease, an interest which culminated in the formation in 1909 of the Rockefeller Sanitary Commission and a gift of $1,000,000 to finance a five-year campaign against the disease. Dr. Stiles became a member of the Commission and was made its scientific secretary, a post which he retained throughout the life of the organization.

The discovery of a new species of hookworm widespread in America, the vigorous campaign for recognition of the public health importance of the parasite and its culmination in the application of extensive control work probably mark the high lights of Dr. Stiles' career. However, during the intervening years he was not idle in other fields. In the meanwhile his report on surra and his "Animal parasites of cattle" had appeared as Bureau of Animal Industry publications. His "Illustrated key to the trematode parasites of man" appeared in 1904, to be followed in 1906 by a similar key to the cestodes of man. In 1905, he conducted an investigation into the cause, transmission and source of Rocky Mountain spotted fever. While Dr. Stiles was unable to confirm the hypothesis that this disease is transmitted by ticks, he did disapprove the contention of Wilson and Chowning that it was caused by a *Piroplasma,* the so-called *Piroplasma hominis.* His later valuable contribution on "The taxonomic value of the microscopic structure of the stigmal plates in the tick genus *Dermacentor*" was probably an outgrowth of his spotted fever investigations.

In 1910, there appeared the monograph by Stiles and Goldberger on an anatomical study of *Watsonius watsoni* and 19 allied species of the superfamily, Paramphistomoidea. This outstanding work represented a very valuable contribution to the internal anatomy of a group requiring prolonged and detailed study.

During the years between 1902 and 1912, Dr. Stiles collaborated with

Dr. Albert Hassall in the preparation of the monumental Index Catalogue of Medical and Veterinary Zoology, which was issued in 36 parts. In addition Dr. Stiles and his associates later prepared and published several subject catalogues which appeared as Hygienic Laboratory Bulletins, as did a number of key-catalogues of various parasites reported from man and other animals. These catalogues constituted a summary of the world's literature on zooparasitic infections, and as such are familiar to every parasitologist.

Stiles had very early in the hookworm work recognized the importance of environmental sanitation and from the beginning the control campaigns which he directed were predicated on the thesis of "80 percent prevention and 20 percent treatment." Naturally, he became involved more and more in the sanitation problem. For instance during his work with the Country Life Commission, he inspected 4,645 farm homes in 6 states and found 55.2 per cent of them without toilet facilities of any sort. These activities led later to intensive rural sanitation campaigns by officers of the United States Public Health Service in cooperation with the State boards of health, during which from 1914 to 1917, a total of 105,157 rural homes, 731 churches and 961 rural schools were inspected for sanitary facilities.

In 1910, Stiles began studies on soil pollution and the survival of parasite cysts and ova under varying conditions. These investigations were interrupted by the first World War but after the war they were resumed and pursued intensively. Of all of Dr. Stiles' work, these studies are probably the least known to parasitologists. However, very important findings came from them and one eminent authority in the field has stated only recently: "The results of ground water pollution studies by Stiles and Crohurst established accurately and for all time the rate and level at which fecal pollution spreads in a medium composed of sand having a subsurface ground-water table."

Following the armistice marking the end of the first World War, some apprehension was felt on the part of public health authorities that soldiers returning from overseas service might serve as unusual sources of infection for the dissemination of *Endamoeba histolytica* and other intestinal parasites. In a survey involving over 8,000 persons, including returned soldiers, soldiers who had not served overseas, civilians, and immigrants, Boeck and Stiles determined that individuals of the first mentioned group were no more frequently infected with *E. histolytica* and other intestinal parasites on the average than were individuals comprising the other groups and that therefore members of the A. E. F. could not be expected to serve as unusual sources of infection in the dissemination of parasitic diseases.

Dr. Stiles was elected secretary of the International Commission on

Zoological Nomenclature at the International Zoological Congress at Cambridge in 1898 and until 1936 served faithfully and untiringly in exerting an influence which had much to do with bringing about proper usage of zoological terminology. He represented the United States at the international congresses at Leyden, 1895, Cambridge, 1898, Berlin, 1901, Berne, 1904, Boston, 1907, Gratz, 1910, Monaco, 1913, Budapest, 1927 and Padua, 1930.

During his long and distinguished career, many honors came to Dr. Stiles. He received honorary M.S. and D.Sc. degrees from Wesleyan University, LL.D. from the University of North Carolina, D.Sc. from Yale and M.D. from the Richmond Medical College. He was a foreign correspondent of the Société de Biologie of France and of the Académie de Médecine of France, a corresponding member of the Zoological Society of London, and an honorary member of other foreign societies.

Dr. Stiles' talents were well illustrated by the scope of his researches and his broad, ever changing horizons. In the light of present day specialization, his versatility was amazing. It enabled him to produce important contributions on nematodes, trematodes, cestodes and arthropods, to achieve conspicuous leadership in the field of zoological nomenclature, to prepare with infinite care and precision outstanding catalogues of incalculable value for all time, and to draft, motivate and participate actively in broad public health programs. Perhaps of all his scientific accomplishments, his influence in the field of public health was most far reaching and yet most undervaluated. In one of his later papers published shortly before his retirement from the Public Health Service, Stiles enumerated ten factors responsible for the marked advancement in public health in the South. Very generously he omitted reference to the influence of his own work in bringing about this advancement. Today the Southern States may well point with pride to their exceptional rural health organizations. There is no doubt but that these organizations had their foundations in the early hookworm work and that the health consciousness of the South was awakened by the message which Dr. Stiles carried into its highways and byways at the turn of the century.—WILLARD H. WRIGHT, *Division of Zoology, National Institute of Health.*

THE OÖCYSTS OF COCCIDIA FROM DOMESTIC CATTLE IN ALABAMA (U. S. A.), WITH DESCRIPTIONS OF TWO NEW SPECIES

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There is little information available on the bovine coccidia to supplement oöcyst studies in the definition of species. The relative pathogenicity, localization in the tissues, and morphology of the intracellular stages of coccidia from bovines have not been worked out on a comparative basis. To be reliable, such information should be based on experimental work with pure cultures and coccidia-free hosts. Considering the difficulties involved in providing these experimental conditions with bovines, a long time will elapse before speciation in these coccidia can be established with a thoroughness approaching that accomplished for chicken coccidia.

The deficiencies in our knowledge of complete life histories and the probable extended period before such information will be available in considerable volume make all the more desirable at the present time a system of diagnosis based on comparative morphology of oöcysts. The present survey of coccidial oöcysts from domestic cattle in the vicinity of the U. S. Regional Animal Disease Research Laboratory at Auburn, Alabama, where this study was made, was carried out to determine whether the groups of oöcysts previously described as species constitute recognizable entities from host to host and, in the event this were true, to determine the species prevalent in bovines from that section of the country. The study revealed 9 distinct groups of oöcysts which were differentiated by morphological and physiological criteria, 7 of these fitting the definitions for described species from bovines while 2 are apparently new. This paper presents comparative descriptions of these oöcysts which, it is hoped, will contribute toward more accurate designations of coccidial infections in bovines under field and experimental conditions.

MATERIALS AND METHODS

Oöcysts for this study were obtained from fecal specimens from calves having natural coccidial infections. Most of the host animals were male and female Jersey calves and a few of the Hereford breed. The entire early natural infection was followed by frequent fecal examinations in 7 healthy calves kept on the premises of the Laboratory. Fecal samples

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were obtained at intervals during August and September, 1938, from 25 unthrifty calves from a dairy herd in the vicinity, most of these animals having shown more or less extensive scouring and emaciation during the second to fifth months of life and occasionally passing diarrheic stools containing blood. Individual specimens were obtained from several host animals from different localities in central Alabama. The calves in which natural infections were followed by frequent examinations provided the best source of material, since each calf after beginning to discharge oöcysts at the age of 4 to 6 weeks remained a continuous source of supply for the following several weeks, and usually discharged oöcysts of most species of bovine coccidia before the initial heavy natural infection subsided.

In the laboratory, flotations were made by mixing small amounts of strained fecal sediment with 15 volumes of 40 per cent sugar solution. After flotation, oöcysts in the surface films were removed with a wire loop 0.6 cm in diameter for observation, measurements and sporulation tests. Photographs, observations and drawings were made on oöcysts in temporary mounts in the flotation fluid, which had satisfactory optical qualities for observation and was ideal for temporary mounts because of high viscosity and slow evaporation. Measurements were made on oöcysts in hanging drops of flotation fluid on 22 mm coverslips inverted over the pits of depression slides. Secondary flotation occurred and oöcysts soon accumulated beneath the surfaces of the coverslips, orienting themselves with their long axes parallel to the surface of the glass. Individual oöcysts were then measured on the scale of an ocular micrometer, and the resulting readings transposed into microns. This method of measuring concentrated the oöcysts into a relatively small space when specimens in a sample were few, and removed the danger of distortion through coverslip pressure. When observations and measurements were made within a few hours after flotation, the sugar solution had no perceptible effect on shape, size or color of oöcysts.

Sporulation times for oöcysts were determined by a refinement of the method described by the writer (1938) for obtaining standard conditions for sporulation of oöcysts of sheep coccidia. Loopfuls of flotation fluid containing freshly discharged oöcysts were placed on 22 mm coverslips and each drop encircled with a strong line made by a wax pencil. Two drops of clean tap water were added to each drop of fluid on a coverslip and the resulting larger drop thoroughly mixed to insure dilution of the sugar solution and allow the oöcysts to sink through the fluid to the surface of the glass. The circle made by the wax pencil served to keep the drop intact. Preparations were made only from loopfuls of flotation material containing little fecal debris, since it was desired to eliminate putrefaction and, therefore, standardize the oxygen supply.

These coverslip preparations were then placed upright on inverted dishes inside a closed Petri dish containing a shallow layer of water to maintain humidity and prevent evaporation from the coverslip drops. Observations for sporulation were made at 24-hour intervals in the following manner: Excess water was removed from each drop by applying the tip of a piece of blotting paper to the edge, care being taken to leave a shallow layer over the oöcysts adhering to the surface of the coverslip. The coverslip was then inverted over the pit of a depression slide, the oöcysts remaining attached to the surface of the glass. Observations were usually made under the high dry objective, but it was possible to use oil immersion when small oöcysts were being observed. At each observation the progress of sporulation was tabulated. Until the sporulation process was complete in oöcysts which were being tested coverslips were returned to the moist chamber for another 24-hour period, care being taken to restore the two drops of water to each preparation. Since all tests were performed at room temperature and aeration and moisture standardized by maintaining similar amounts of clean water in all preparations, the results of sporulation tests became comparative and proved to be a valuable accessory criterion for the identification of certain oöcysts.

DESCRIPTION OF SPECIES

Eimeria zurnii (Rivolta, 1878) Martin, 1909
(Plate I, 2; Plate II, 12)

Synonyms: Cytospermium zurnii Rivolta, 1878; *Coccidium bovis* Züblin, 1908, pro parte; *Eimeria bovis* (Züblin, 1908) Fiebiger, 1912, pro parte; *Eimeria canadensis* Bruce, 1921, pro parte.

Unsporulated oöcysts: Oöcysts of *E. zurnii* from Alabama calves measured 15 to 22 (average 17.8) μ long by 13 to 18 (average 15.6) μ in transdiameter; 20 to 40 consecutive oöcysts were measured from each of 5 host animals, dimensions being based on a total of 140. Shape spherical to bluntly ellipsoidal; oöcysts 0.73 to 1.00 (average 0.88) as broad as long. No micropyle visible. Wall thin, homogeneous, transparent, of uniform thickness throughout; the oöcysts appear colorless under low magnification, but under oil immersion the wall shows a faint grayish-lavender tint, fading to light yellow at one end. In pure discharges these oöcysts comprise a uniform, well-defined group.

Sporulation: In 4 trials at room temperature 76 to 100 per cent of the oöcysts sporulated completely within 48 to 72 hours after isolation into a drop of clean tap water.

Relationships: The more ellipsoidal oöcysts of *E. zurnii* may be confused with those of *E. ellipsoidalis*, which are usually found in large numbers in feces from healthy calves rather than in diarrheic feces from calves with clinical coccidiosis. The smaller subspherical oöcysts of the species resemble those of *E. subspherica* morphologically, but they sporulate faster, have sturdier walls and are usually associated with clinical coccidiosis.

Occurrence: Oöcysts of *E. zurnii* are often associated in pure or nearly pure infection with bloody, diarrheic feces or bloody mucus from calves, indicating that this species is probably highly pathogenic. In the present study large numbers of oöcysts of *E. zurnii* were found in pure infection in scouring calves, once in bloody mucus and once in slightly bloody, diarrheic feces; in another bloody, diarrheic

stool and in a diarrheic stool with no blood, oöcysts of *E. zurnii* comprised at least 95 per cent of the total oöcyst count, while oöcysts of *E. bovis* constituted the remainder.

Although others had indicated that there were at least two types of coccidial oöcysts to be found in feces from domestic cattle, it remained for Yakimov and Galouzo (1927) to separate the ovoidal oöcysts mentioned by the earlier investigators from those described as spherical. They retained the name *E. zurnii* for the spherical oöcysts and gave the dimensions as 17.1 μ in diameter, with a range of 15.3 to 19.1 μ. The larger, ovoidal oöcysts were described by these writers as *E. smithi*. While the oöcysts of *E. zurnii* found in diarrheic calves from Alabama were similar in size to those measured by Yakimov and Galouzo, the usual oöcyst was found to be subspherical rather than regularly spherical, with a range in shape from spherical to bluntly ellipsoidal.

Rivolta (1878) did not give sufficient information to enable later investigators to determine accurately which species of bovine coccidia he meant in his description of *Cytospermium zurnii,* later properly referred to the genus *Eimeria*. Since he was dealing with coccidia associated with bloody dysentery in young cattle, it has been assumed that he was describing the coccidium represented by the spherical and subspherical oöcysts frequently associated with bloody diarrhea in calves and later specified for *E. zurnii* by Yakimov and Galouzo. Rivolta is therefore credited with authorship of the species.

In his *Coccidium bovis,* Züblin (1908) described oöcysts of at least 2 species, including those fitting the description of *E. zurnii*. Most of the coccidia from bovines were said by this writer to be "runde oder ovale." and to have a "Durchmesser von 0,012 : 0,010 Millimeter bis 0,025 : 0.020 mm." While these dimensions have sufficient range to fit oöcysts of several species of cattle coccidia, Züblin's statement that rounded or spherical ("kugelig") forms predominated in numbers and the fact that his observations were made on animals with clinical coccidiosis make it reasonably certain that his *E. bovis* included oöcysts defined as *E. zurnii*. It appears, therefore, that Becker (1934) was justified in synonymizing *E. bovis* in part with *E. zurnii*.

Bruce (1921) described *E. canadensis* from coccidia from cattle in British Columbia. The oöcysts were said to be spherical, ellipsoidal and ovoidal in shape and to vary from 11.6 to 43.1 μ in length and from 11.6 to 27.8 μ in breadth. His figures included several bluntly ellipsoidal to spherical oöcysts measuring 16.6 to 18.2 μ by 13.2 to 17.4 μ, dimensions which fall within the range for *E. zurnii*. Since there is little doubt that Bruce included *E. zurnii* in his species, Becker (1934) was justified in synonymizing the name *E. canadensis* in part with the earlier species.

Eimeria bovis (Züblin, 1908) Fiebiger, 1912
(Plate I, 7; Plate II, 17)

Synonyms: Coccidium bovis Züblin, 1908, pro parte; *Eimeria canadensis* Bruce, 1921, pro parte; *Eimeria smithi* Yakimov and Galouzo, 1927.

Unsporulated oöcysts: Oöcysts of this species from Alabama calves measured 23 to 34 (average 27.7) μ long by 17 to 23 (average 20.3) μ in transdiameter; 10 to 40 consecutive oöcysts were measured from each of 25 fecal specimens from 8 host animals, dimensions being based on a total of 500. Shape typically stout ovoidal, but somewhat blunted across narrow end; variation considerable, especially in heavy discharges, with subellipsoidal, asymmetrical and elongated, sharply tapered oöcysts occurring at extremes; 0.56 to 0.88 (average 0.73) as broad as long. Micropyle present as a gap in wall at tapered end of oöcyst, but perceived as a lightened area rather than as a definite opening. Wall homogeneous, transparent and slightly thinner toward micropylar end. The pale, cloudy, greenish- to yellowish-brown color of these oöcysts under low magnification is intermediate between that of the relatively colorless oöcysts of *E. zurnii* and the distinctly yellowish-brown oöcysts of *E. auburnensis.*

Sporulation: In 10 trials at room temperature 63 to 100 per cent of the oöcysts of *E. bovis* sporulated completely within 48 to 72 hours after isolation into a drop of clean tap water.

Relationships: The general shape of typical oöcysts of *E. bovis* is similar to that for *E. alabamensis,* but oöcysts of *E. bovis* are considerably larger, sporulate faster, and do not have such delicate walls. Oöcysts of *E. bovis* are significantly smaller than those of *E. auburnensis* or *E. bukidnonensis,* which are also tapered toward one end; the wall shows no tendency toward a roughened phase as in *E. auburnensis* and is not thickened as in *E. bukidnonensis.* In color, oöcysts of *E. bovis* are about intermediate between the relatively colorless *E. alabamensis* and the distinctly yellowish-brown *E. auburnensis.*

Occurrence: Oöcysts of *E. bovis* were frequently found in large numbers in feces from healthy calves with natural infections. They were occasionally found associated with those of *E. zurnii* in stools from emaciated, scouring calves.

In describing coccidia associated with bloody dysentery in cattle, Züblin (1908) stated that occasionally "betrug die Breite 0,020 mm, die Länge 0,030–0,035 mm," although predominantly they were said to be "runde oder ovale" and to measure "0,012 : 0,010 Millimeter bis 0,025 : 0,020 mm." Comparing the bovine coccidia with those known from the rabbit, Züblin added that the forms from cattle were almost exclusively spherical ("kugelig"), rarely ellipsoidal ("länglich rund"), while occasionally larger, egg-shaped specimens ("grössere, eiförmige Exemplare") were found. Züblin concluded in his summary that the coccidium from cattle, which he named *Coccidium bovis,* was "rundlich" and measured 0.015 mm in length by 0.012 mm in breadth. No mention was made here of the "ovale" or "grössere, eiförmige" oöcysts described in the body of the paper, but since Züblin did not distinguish more than one coccidium from cattle the presumption is that he included these forms in his *E. bovis.*

Since Züblin was dealing with coccidia from animals with coccidial dysentery, it seems to be a safe conclusion that the oöcysts he described as "rundlich" or "kugelig" were those later defined for *E. zurnii.* On the basis of size only, his relatively rare, larger oöcysts measuring 30 to

35 μ in length by 20 μ in transdiameter might be included with narrower oöcysts of *E. canadensis* or with larger oöcysts of the coccidium described as *E. smithi* by Yakimov and Galouzo (1927) from ovoidal oöcysts measuring 25.2 to 32.4 (average 31.5) μ in length by 19.8 to 28.8 (average 21.6) μ in transdiameter. However, Züblin's additional statement that occasionally "grössere, eiförmige" specimens occurred creates the strong impression that this description applied to the oöcysts measuring 30 to 35 μ by 20 μ. If this is true, these oöcysts fit the description of the ovoidal *E. smithi* rather than the ellipsoidal *E. canadensis*. Becker (1934) evidently considered that the original description of *E. bovis* included oöcysts later described for *E. smithi*, since he synonymized the former in part with *E. smithi*, which he designated as the valid name for the species.

While there may be some doubt as to whether Züblin's oöcysts measuring 30 to 35 μ in length by 20 μ in breadth are those he described as "grössere, eiförmige Exemplare," the inference that these descriptions apply to the same oöcysts seems to be strong enough to warrant the opinion that part of this author's *E. bovis* represents the coccidium later described as *E. smithi*. The present writer feels that the name *E. bovis* should be retained because part of the description of this species defines with reasonable accuracy oöcysts later described for *E. smithi*. Under this opinion, the name *E. bovis* is restricted to apply only to the oöcysts in question, and the name *E. smithi* is reduced to synonymy.

Eimeria canadensis Bruce, 1921
(Plate I, 8; Plate II, 19, 20)

Synonym: Eimeria zurnabadensis Yakimov, 1931.

Unsporulated oöcysts: Oöcysts answering the description for this species from Alabama calves measured 28 to 37 (average 32.5) μ long by 20 to 27 (average 23.4) μ in transdiameter; 5 to 30 oöcysts were measured from each of 10 fecal samples from 8 host animals, dimensions being based on a total of 170. Shape typically regularly ellipsoidal, varying from nearly cylindrical to stoutly ellipsoidal, with a few specimens being slightly tapered; 0.62 to 0.85 (average 0.72) as broad as long. Micropyle an inconspicuous gap in wall at one end, appearing covered with a thin, dark refraction line which possibly represents an operculum. Wall transparent, about 1 μ in thickness in main body of oöcyst, slightly thinner at each end; impregnated with brown, fading to paler yellowish-brown toward ends, imparting a delicate tint to oöcyst. Oöcyst membrane distinguishable from inner surface of wall, the two not forming the single, heavy refraction line characteristic of smaller oöcysts. These are relatively large, stoutly ellipsoidal, delicately yellowish-brown oöcysts.

Sporulation: In 6 trials at room temperature 66 to 100 per cent of the oöcysts observed required 72 to 96 hours for complete sporulation after isolation into a drop of clean tap water. At the end of 48 hours in preparations containing both oöcysts of this species and of *E. auburnensis*, all of the oöcysts of *E. canadensis* were still in the undivided sporont stage, while those of *E. auburnensis* had developed as far as the elongated sporoblast stage.

Relationships: Oöcysts of *E. canadensis* are similar to those of *E. auburnensis* in color, and slightly tapered variants of the former may be confused with smaller specimens of the latter. The oöcysts of *E. canadensis* can be differentiated from those of *E. auburnensis*, however, by having a significantly smaller mean size, greater

ratio of breadth to length and by requiring 24 hours longer for complete sporulation under standard conditions. In addition, the heavily-mammillated wall observed in certain variants of *E. auburnensis* was not seen in oöcysts of *E. canadensis.* In a few oöcysts of this species, however, roughened walls were seen, the roughening consisting of relatively few broad, gently rounded, shield-like plaques instead of the numerous small, sharply rounded elevations characteristic of oöcysts of *E. auburnensis.* While oöcysts with roughened walls probably represent specimens discharged from the tissues of the host before the wall has completely homogenized it is apparent that the tendency for premature discharge of oöcysts is more marked in *E. auburnensis* than in *E. canadensis* or other species of bovine coccidia.

Occurrence: Oöcysts of this species were found in fecal samples from several healthy Alabama calves during the course of the early natural infection, but never in great numbers.

In a brief preliminary report, Yakimov (1931) described *E. zurnabadensis* on the basis of oöcysts from the zebu, later (1933) giving a more detailed description accompanied by a figure. The oöcysts were said to measure 25.2 to 43.2 (average 34.1) μ long by 18 to 32.4 (average 25) μ in transdiameter, were more or less cylindrical in shape, with the two ends equally rounded, and were colorless to yellowish in tint.

In his *E. canadensis,* Bruce (1921) included along with *E. zurnii* and *E. bovis* oöcysts answering the description for Yakimov's *E. zurnabadensis.* He stated that larger oöcysts of *E. canadensis* were always ovoidal or ellipsoidal in shape, including among his figures four of the large, ellipsoidal oöcysts having shapes, dimensions and form indexes within the range specified by Yakimov for *E. zurnabadensis.* Parts of Bruce's *E. canadensis* have been synonymized with both *E. zurnii* and *E. bovis,* but since the remaining part of the description adequately designates oöcysts later described as *E. zurnabadensis,* the name *E. canadensis* should be retained, restricted to apply only to these large, ellipsoidal oöcysts and the name *E. zurnabadensis* reduced to synonymy.

While the average dimensions of oöcysts answering the description for *E. canadensis* from Alabama calves were slightly smaller than those given by Yakimov, the shape index was almost identical. The four specimens figured by Bruce measured 30.7 to 33.2 μ long by 24.9 to 26.5 μ in transdiameter, dimensions which place them well within the range specified for the species by Yakimov.

Eimeria ellipsoidalis Becker and Frye, 1929
(Plate I, 3; Plate II, 13)

Unsporulated oöcysts: Oöcysts answering the description for this species from Alabama calves measured 12 to 27 (average 16.9) μ long by 10 to 18 (average 13) μ in transdiameter; 25 to 100 consecutive oöcysts were measured from each of 9 fecal samples from 4 host animals, dimensions being based on a total of 350. Shape predominantly regularly ellipsoidal, but varying from spherical to almost cylindrical, the spherical and subspherical oöcysts occurring in the smaller range; 0.62 to 1.00 (average 0.77) as broad as long. Micropyle imperceptible. Wall thin, homogeneous, transparent, and slightly thinner and paler at one end of the oöcyst to suggest a possible micropyle or weakness in the wall. Under low magnification these oöcysts

appear colorless, but under oil immersion the wall is observed to have a pale lavender to yellowish tint.

Sporulation: In 13 trials at room temperature 52 to 100 per cent of the typically ellipsoidal oöcysts sporulated completely within 48 to 72 hours after isolation into a drop of clean tap water.

Relationships: Spherical or subspherical oöcysts in the small range of this species may be confused with those of *E. subspherica* or smaller *E. zurnii,* and elongated oöcysts in the larger range of *E. ellipsoidalis* intergrade with oöcysts described for *E. cylindrica.* The standardized sporulation test showed that the oöcysts of *E. ellipsoidalis* require at least 48 hours less for complete sporulation than those of *E. subspherica.* The prevalence of oöcysts of *E. ellipsoidalis* in feces from healthy calves and the frequent association of oöcysts of *E. zurnii* with clinical symptoms of coccidiosis may possibly indicate a significant difference in the pathogenicity of these two species under field conditions. Wilson (1931) has presented fairly convincing experimental evidence that *E. cylindrica* is a valid species, in spite of the tendency for the oöcysts to intergrade morphologically with those of *E. ellipsoidalis.*

Occurrence: These colorless, ellipsoidal oöcysts were found in greater frequency and numbers in feces from healthy Alabama calves examined repeatedly during the early natural infection than were those of any other species.

Becker and Frye (1929) described this species from oöcysts found in the feces of a single calf. The oöcysts were 20 to 26 (average 23.4) μ long by 13 to 17 (average 15.9) μ in transdiameter, were predominantly ellipsoidal in shape, with ovoidal or subspherical forms being rare, and were colorless and more inconspicuous than oöcysts of *E. bovis.* In this study, measurements of several hundred oöcysts from several hosts showed a smaller average size and greater range in size than were recorded by Becker and Frye for oöcysts from a single host. Occasionally oöcysts in a single fecal specimen showed dimensions similar to those given by these authors. For example, 50 consecutive ellipsoidal oöcysts in one fecal sample from a calf measured 17 to 27 (average 22.4) μ long by 13 to 17 (average 15.4) μ in transdiameter. Three days later, 20 consecutive ellipsoidal oöcysts in a fecal specimen from the same calf measured 16 to 24 (average 19.7) μ long by 12 to 16 (average 14.1) μ in transdiameter. Apparently the oöcysts in a single fecal specimen from a calf do not represent the entire range for the species. Measurements of oöcysts from calves artificially infected with pure cultures of oöcysts of *E. ellipsoidalis* are needed to define fully the mean size and range in size for oöcysts of this species.

Eimeria bukidnonensis Tubangui, 1931
(Plate I, 6; Plate II, 18)

Unsporulated oöcysts: Oöcysts of this species from Alabama calves measured 33 to 41 (average 36.6) μ long by 24 to 28 (average 26.7) μ in transdiameter; 10 to 25 consecutive oöcysts were measured from each of 4 fecal samples from 3 host animals, dimensions being based on a total of 80. Practically all oöcysts distinctly pyriform, with little variation in shape; 0.63 to 0.80 (average 0.73) as broad as long. Color yellowish-brown to distinctly brown. Wall about 2 μ thick, discontinuous at narrow end to form a micropyle about 4 μ in diameter; thickness of wall relatively greater than in any other species of coccidia from bovines.

Sporulation: In 4 trials at room temperature 90 to 96 per cent of these oöcysts

sporulated completely within 4 to 7 days after isolation into a drop of clean tap water.

Relationships: Oöcysts of this species were easily differentiated from those of all other species of bovine coccidia by their large size, distinctly brown color, thick wall, pyriform shape and long sporulation time.

Occurrence: Oöcysts of *E. bukidnonensis* were never found in large numbers or great frequency in Alabama calves, and probably this species has little pathogenic significance.

The specimens observed in Alabama were considerably smaller than those described for the species by Tubangui (1931), his oöcysts measuring 46.8 to 50.4 (average 48.6) μ long by 33.3 to 37.8 (average 35.4) μ in transdiameter.

Eimeria cylindrica Wilson, 1931
(Plate I, 4; Plate II, 14)

Unsporulated oöcysts: Oöcysts answering the description for this species from Alabama calves measured 16 to 27 (average 23) μ long by 12 to 15 (average 13.9) μ in transdiameter; these dimensions were based on measurements of 66 consecutive oöcysts from a fecal sample in which there were no other morphologically related oöcysts. Shape typically regularly cylindrical, the opposite sides of the oöcyst being nearly parallel throughout the middle third of the long axis; oöcysts vary from ellipsoidal to narrow cylinders twice as long as broad; 0.50 to 0.77 (average 0.60) as broad as long. Micropyle imperceptible. Wall thin, homogeneous, transparent, slightly paler at one end to suggest a possible micropyle. Oöcysts appear colorless under low magnification, but under oil immersion the wall appears slightly tinted.

Sporulation: In 2 trials at room temperature 90 and 95 per cent of the typically cylindrical oöcysts appeared to be sporulated within 48 hours after isolation into clean water. The number of tests was not sufficient to be conclusive, but the results indicated that these oöcysts sporulated at a faster rate than those of *E. ellipsoidalis,* which require 48 to 72 hours under identical conditions.

Relationships: These cylindrical oöcysts were often found associated with those of *E. ellipsoidalis,* and since morphological intergradation was noted between the two an accurate differential diagnosis was difficult in these mixed discharges. Occasionally, however, the cylindrical oöcysts were found with few or no oöcysts of *E. ellipsoidalis,* and from these it was possible to make what is believed to be a reasonably accurate description of the species. Average oöcysts of the two species are distinct in shape and ratio of breadth to length. The possible diagnostic differences in pathogenicity and in sporulation time between the two groups of oöcysts should be tested further.

Occurrence: Oöcysts of *E. cylindrica* were usually found during the initial natural infection in feces from healthy calves examined repeatedly, but with less frequency and in smaller numbers than those of *E. ellipsoidalis.*

On oöcyst morphology alone the distinction between *E. cylindrica* and *E. ellipsoidalis* seems weak, but Wilson (1931) presented additional evidence which indicates that *E. cylindrica* is probably a valid species with pathogenic potentialities. The oöcysts described by Wilson for the species measured 19.4 to 26.8 (average 23.3) μ long by 11.9 to 14.9 (average 13.3) μ in transdiameter, and were less resistant to freezing temperature and sporulated faster than oöcysts of either *E. zurnii* or *E. bovis.* He recovered typical cylindrical oöcysts in pure discharge from a calf from the eleventh to the twentieth day after experimental dosage, and noted that the feces were streaked with blood on the sixth day after dosage, indicating possible pathogenicity for this species. Additional experi-

mental work is needed to determine accurately the mean size and range in size of oöcysts of *E. cylindrica,* and to clearly differentiate this species from the earlier described *E. ellipsoidalis.* Until more information is available, it seems advisable to retain the name *E. cylindrica* for the oöcysts in question.

Eimeria auburnensis Christensen and Porter, 1939
(Plate I, 9, 10; Plate II, 21, 22)

Unsporulated oöcysts: Oöcysts 32 to 45.5 (average 38.4)μ long by 20 to 25.5 (average 23.1)μ in transdiameter. Shape typically elongated ovoidal, varying between subellipsoidal and markedly tapered; 0.48 to 0.76 (average 0.60) as broad as long. Micropyle a gap in wall at tapered end, covered with a thin, black line which possibly represents an operculum. Wall typically smooth, homogeneous, transparent, and usually noticeably yellowish-brown in tint, but varying in structure from the usual transparent, homogeneous type to a relatively rare, semi-transparent, heavily-mammillated type, with all intergradations of wall roughening between the two extremes; the smooth-walled variants were found in more host animals and usually in greater numbers than the rough-walled variants.

Sporulation: In 4 trials at room temperature 91 to 100 per cent of the oöcysts sporulated completely within 48 to 72 hours after isolation into a drop of clean tap water.

Relationships: The oöcysts of *E. auburnensis* are differentiated from those of *E. bovis* by their greater size, more intense coloration, relatively narrower and more elongated form, and in their tendency toward the development of the mammillations in the wall. They differ from those of *E. bukidnonensis* in having a thinner wall, paler brownish tint, greater transparency, shorter sporulation time, relatively narrower form, and by the occasional formation of the mammillated wall. They are distinguished from oöcysts of *E. thianethi* in having a smaller average size and thinner wall, and in not showing the transverse striations in the wall as reported for oöcysts of *E. thianethi* by Gwéléssiany (1935).

Occurrence: Oöcysts of *E. auburnensis* were frequently found in small or moderate numbers in feces from healthy calves. The smooth-walled variants occurred more frequently than the rough-walled forms, which were relatively rare.

This species was described in detail by the writer and Porter (1939) from oöcysts found in feces from several calves from Alabama and a few fecal specimens obtained from Maryland and Montana. In addition to the morphological evidence they presented for the separate identity of *E. auburnensis,* these writers infected a calf with a pure culture of predominantly rough-coated oöcysts of the species and produced a profuse diarrhea from the 9th to 13th days after dosage, followed by heavy discharge from the 24th to the 27th days after dosage of oöcysts showing uniformity in size, shape, color, and sporulation time, and showing a completely intergrading series in wall structure from homogeneous to heavily-mammillated. The potential pathogenicity of the species was shown by the production of scours in this experimental infection.

Eimeria alabamensis n. sp.
(Plate I, 5; Plate II, 15, 16)

Unsporulated oöcysts: Oöcysts 13 to 24 (average 18.9)μ long by 11 to 16 (average 13.4)μ in transdiameter; 7 to 48 consecutive oöcysts measured from each of 10

fecal samples from 4 host animals, dimensions being based on a total of 200. Shape typically pyriform, but showing considerable variation (Fig. 1, C–K); subellipsoidal and subcylindrical oöcysts occur throughout entire range and intergrade perfectly with the majority that are distinctly tapered at one end; asymmetrical forms common in heavier discharges; 0.50 to 0.86 (average 0.71) as broad as long. No micropyle perceptible. Wall thin, delicate, homogeneous, transparent, slightly thinner at narrow end; oöcysts appear colorless and crystalline under low magnification, but under oil immersion the wall is observed to have a grayish-lavender to pale brownish-yellow tint, fading to light yellow at narrow end. Early spherical sporont shows layer of refractile granules in regular arrangement about periphery, giving a beaded appearance (Fig. 1, G).

Sporulation: In 5 trials at room temperature freshly discharged oöcysts required 96 to 120 hours for complete sporulation after isolation into clean tap water, 82 to 100 per cent completing the process during this interval. Characteristic of this species was the presence of a parachute-shaped cap at each end of the sporocyst immediately preceding segmentation of the protoplasm into sporozoites (Fig. 1, H).

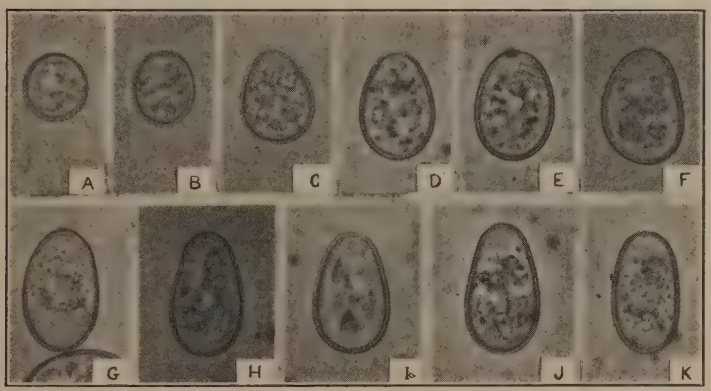

FIG. 1. A, B, oöcysts of *Eimeria subspherica,* showing range of variation in shape. C–K, oöcysts of *E. alabamensis,* showing range of variation in shape. Photographed by Dale A. Porter.

These cap-like structures disappeared upon completion of sporulation. A sporulated oöcyst contained 4 elongated, gently tapered sporocysts, each having 2 indistinct sporozoites. No residual material was observed in either oöcyst or sporocyst.

Relationships: In shape the typical oöcysts of *E. alabamensis* resemble those of *E. bovis,* but in mean size they are significantly smaller and sporulation under standardized conditions requires 48 hours longer. Subellipsoidal or subcylindrical oöcysts of this species resemble the oöcysts of *E. ellipsoidalis* or *E. cylindrica* in color, size, and shape, but are easily distinguished from them by requiring at least 48 hours longer for sporulation. After remaining for 24 hours in a hanging drop of the 40 per cent sugar solution used for flotation, the delicate walls of oöcysts of this species were crumpled, while those of oöcysts of *E. bovis, E. ellipsoidalis* and *E. cylindrica* remained intact.

Occurrence: Oöcysts of *E. alabamensis* were found in small or moderate numbers in feces from several healthy Alabama calves, in one fecal specimen being the only oöcysts present.

Eimeria subspherica n. sp.
(Plate I, 1; Plate II, 11)

Unsporulated oöcysts: Oöcysts 9 to 13 (average 11)μ long by 8 to 12 (average 10.4)μ in transdiameter; 5 to 30 consecutive oöcysts measured from each of 11 fecal samples from 6 host animals, dimensions being based on a total of 115. Shape typically subspherical, varying from spherical to bluntly ellipsoidal (Fig. 1, A, B); 0.75 to 1.00 (average 0.94) as broad as long. No micropyle visible. Wall thin, homogeneous, transparent, of uniform thickness throughout; oöcysts appear pale and colorless under low magnification, but the wall shows a faint yellow tint under oil immersion. These are pallid, fragile oöcysts, and the smallest observed from calves in Alabama.

Sporulation: In 5 trials at room temperature freshly discharged oöcysts of this species required 96 to 120 hours for complete sporulation after isolation into clean tap water, 86 to 98 per cent of them completing the process within this interval. In drops containing both oöcysts of this species and of *E. ellipsoidalis,* those of the latter had completely sporulated before those of *E. subspherica* had developed beyond the spherical sporont stage. A sporulated oöcyst of *E. subspherica* contained 4 pale, spindle-shaped sporocysts each having 2 indistinct sporozoites. No residual material was observed in either oöcyst or sporocyst.

Relationships: Morphologically these oöcysts may be confused with subspherical oöcysts in the small range of *E. ellipsoidalis* and with smaller oöcysts of *E. zurnii,* but they may be differentiated from these forms by their more fragile appearance, more delicate wall, and by requiring 48 hours longer for complete sporulation under standard conditions. After remaining for 24 hours in a hanging drop of the 40 per cent sugar solution used for flotation, the walls of these oöcysts were crumpled, while those of *E. ellipsoidalis* in the same preparations remained intact.

Occurrence: Oöcysts of *E. subspherica* were found in fecal specimens from 6 healthy calves in the vicinity of Auburn, Alabama, never in large numbers. In one fecal specimen they were the only oöcysts present, and in another sample at least 95 per cent belonged to this species. Oöcysts of *E. subspherica* were the only oöcysts in addition to those of *E. zurnii* in the feces of a calf that died of coccidiosis at the age of 5 weeks.

IDENTIFICATION OF OÖCYSTS OF BOVINE COCCIDIA

In identification, freshly discharged oöcysts were found to be most typical of a species in color and shape, and for this reason the unsporulated oöcyst is emphasized in this paper. An additional advantage in obtaining fresh fecal specimens was that preparations could be made for determining sporulation times of oöcysts, which provided valuable information in differentiation in certain cases. On the basis of morphology of unsporulated oöcysts and on sporulation times under standardized conditions, oöcysts of bovine coccidia from Alabama calves fell into 9 more or less well-defined groups, 7 of these belonging to established species while 2 are, as already stated, apparently new. In cases where morphological intergradation occurred, differences in sporulation time were helpful in final differentiation. These groups of oöcysts constituted recognizable entities from host to host.

On gross examination, typical oöcysts of species of bovine coccidia observed in Alabama were colorless (*E. subspherica* n. sp., *E. zurnii, E. alabamensis* n. sp., *E. ellipsoidalis,* and *E. cylindrica*); almost colorless to pale yellowish- or greenish-brown (*E. bovis*); pale to noticeably yellow-

ish-brown (*E. canadensis, E. auburnensis*); distinctly yellowish-brown to brown (*E. bukidnonensis*). In shape the oöcysts were subspherical (*E. subspherica, E. zurnii*); ellipsoidal (*E. ellipsoidalis, E. canadensis*); cylindrical (*E. cylindrica*); stoutly ovoidal to pyriform (*E. alabamensis, E. bovis, E. bukidnonensis*); elongated ovoidal (*E. auburnensis*). Colorless oöcysts were smallest in size, tinted ones larger, although under oil immersion even the smallest oöcysts were observed to have some color in the walls, usually varying from pale lavender to light yellow. The wall was homogeneous, thin and transparent in all species except *E. auburnensis* and *E. bukidnonensis;* the heavily-mammillated wall observed in the rough-coated variants of *E. auburnensis* presented a semi-opaque appearance, although in most oöcysts of the species the wall was smooth; the wall in oöcysts of *E. bukidnonensis* was relatively thicker than in any other species and has been described as radially striated, but this was not marked in specimens observed in this study. All oöcysts of bovine coccidia known at present are without polar caps, and micropylar openings were seen only in the larger oöcysts. Only in oöcysts of *E. alabamensis* did the undivided, spherical sporont have a characteristic appearance, the refractile granules arranging themselves in a bead-like layer about the periphery preceding division.

After freshly discharged oöcysts were isolated into small identical amounts of clean water to standardize the environment and were incubated at room temperature, it was found that the time required for complete sporulation varied considerably among the oöcysts of different species. There was some indication that oöcysts of *E. cylindrica* sporulated fastest of all, finishing the process within 24 to 48 hours, although the number of tests with this form was too few to be conclusive. Repeated tests showed that characteristic sporulation times for oöcysts of the other species were 48 to 72 hours (*E. zurnii, E. ellipsoidalis, E. bovis, E. auburnensis*); 72 to 96 hours (*E. canadensis*); 96 to 120 hours (*E. subspherica, E. alabamensis*); 96 to 168 hours (*E. bukidnonensis*). These sporulation periods, which were found to be constant for a species once standardized conditions were established, provided valuable accessory information in differentiating oöcysts of *E. subspherica* from subspherical *E. ellipsoidalis, E. alabamensis* from *E. bovis,* and *E. canadensis* from *E. auburnensis.*

In the sporulated oöcyst there was little to assist in the differentiation of species. None of the oöcysts showed oöcystic residual material after sporulation; the presence or absence of residual material inside the sporocysts could not be determined with certainty in smaller oöcysts and did not seem to constitute a good differential character. Dimensions of sporocysts were not considered diagnostic and were omitted, since their size is a function of the size of the oöcyst.

Although the 9 groups of oöcysts described here as species are recognizable from morphological and physiological characteristics, there is limited clinical and experimental evidence which indicates that certain of these are probably well-defined species. The frequent association, alone or with few oöcysts of other species, of the subspherical oöcysts described for *E. zurnii* with bloody diarrhea in calves indicates that probably this is a well-defined species with marked pathogenicity. Wilson (1931) recovered oöcysts of *E. cylindrica* in pure discharge from an experimentally infected calf, and the potential pathogenicity was indicated by the appearance of blood-streaked feces on the sixth day after dosage. The writer and Porter (1939) showed that *E. auburnensis* is capable of pathogenic activities by producing severe diarrhea lasting for several days in a young calf by inoculation with a pure culture of infective oöcysts.

Oöcysts of the species of *Eimeria* described in this paper may be differentiated with the aid of the following key:

KEY TO OÖCYSTS OF *Eimeria* FOUND IN CALVES

1. Relatively small and colorless; without perceptible micropyle 2
   Relatively large and tinted; micropyle a gap in wall at one end of oöcyst 6
2. Typical oöcysts subspherical or spherical 3
   Typical oöcysts pyriform, ellipsoidal or cylindrical 4
3. Relatively small; 9 to 13 μ long; pallid, thin-walled, delicate; 96 to 120 hours required for complete sporulation ..... *E. subspherica* n. sp.
   Larger; 15 to 22 μ long; more conspicuous and crystalline in appearance; 48 to 72 hours required for complete sporulation ..... *E. zurnii* (Rivolta, 1878)
4. Typical oöcysts distinctly pyriform, but varying from subellipsoidal to subcylindrical; 13 to 24 μ long; pallid, thin-walled, delicate; peculiar parachute-shaped caps at ends of sporocysts preceding sporozoite formation; 96 to 120 hours required for complete sporulation ..... *E. alabamensis* n. sp.
   Typical oöcysts regularly ellipsoidal or cylindrical; more conspicuous and less fragile than oöcysts of *E. alabamensis* 5
5. Majority of specimens regularly ellipsoidal, varying from spherical to nearly cylindrical; 12 to 27 μ long; 0.62 to 1.00 (average 0.77) as broad as long; 48 to 72 hours required for complete sporulation.
   E. ellipsoidalis Becker and Frye, 1929
   Majority of specimens regularly cylindrical, varying from ellipsoidal to narrowly cylindrical; 16 to 27 μ long; 0.50 to 0.77 (average 0.60) as broad as long; 48 hours or less required for complete sporulation. .... *E. cylindrica* Wilson, 1931
6. Typical oöcysts regularly ellipsoidal, with some slightly tapered or nearly cylindrical forms in range of variation; 28 to 37 μ long; wall homogeneous, delicately yellowish-brown; 72 to 96 hours required for complete sporulation.
   E. canadensis Bruce, 1921
   Typical oöcysts tapered toward micropylar end 7
7. Wall distinctly thickened and yellowish-brown to dark brown in color, these being the most intensely tinted oöcysts noted from bovines; 33 to 41 μ long; pyriform; 96 to 168 hours required for complete sporulation.
   E. bukidnonensis Tubangui, 1931
   Wall not distinctly thickened or so intensely tinted; 48 to 72 hours required for complete sporulation 8
8. Typical oöcysts stoutly egg-shaped or ovoidal; 23 to 34 μ long; almost colorless

to pale greenish- or yellowish-brown; wall smooth and homogeneous in all specimens ..... *E. bovis* (Züblin, 1908)

Typical oöcysts elongated ovoidal; 32 to 46 μ long; pale to distinctly yellowish-brown; wall typically homogeneous, but variants occur having numerous, small, rounded mammillations in the wall.

E. auburnensis Christensen and Porter, 1939

SUMMARY

Nine groups of coccidial oöcysts of the genus *Eimeria* were found in feces from healthy and scouring calves in Alabama, seven fitting the descriptions of established species while two appeared to have been previously undescribed. These oöcysts were differentiated largely on the basis of morphology and sporulation times under standardized conditions. The oöcysts redescribed as *E. zurnii, E. bovis, E. canadensis, E. bukidnonensis* and *E. auburnensis* appeared to represent fairly well-defined groups. Morphological intergradation was noted between oöcysts answering the descriptions for *E. ellipsoidalis* and *E. cylindrica,* but other evidence is presented which indicates the probable specificity of these two forms. Further information, however, is needed to conclusively determine the validity of *E. cylindrica,* the more recently described of the two species. Two new species, *E. alabamensis* and *E. subspherica,* are described from oöcysts which appear to be sufficiently distinct from all other bovine coccidia to warrant specific identity. The names *E. bovis* and *E. canadensis* were considered valid and were retained to define oöcysts later described as *E. smithi* and *E. zurnabadensis,* respectively, which were reduced to synonymy.

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EXPLANATION OF PLATES

PLATE I

These figures of oöcysts of bovine coccidia were drawn with the aid of a camera lucida from specimens that had been discharged from the host animals long enough to allow the protoplasm to assume spherical shape. Size relationships are preserved. The projected scale shows dimensions in microns.

1. *Eimeria subspherica.*
2. *E. zurnii.*
3. *E. ellipsoidalis.*
4. *E. cylindrica.*
5. *E. alabamensis.*
6. *E. bukidnonensis.*
7. *E. bovis.*
8. *E. canadensis.*
9. *E. auburnensis,* specimen with homogeneous wall.
10. *E. auburnensis,* specimen with mammillated wall.

PLATE II

These photographs of oöcysts of bovine coccidia were made from temporary mounts of specimens floated and mounted in 40 per cent sugar solution. Size relationships are preserved. Photographed by Dale A. Porter.

11. *Eimeria subspherica,* unsporulated.
12. *E. zurnii,* unsporulated.
13. *E. ellipsoidalis,* unsporulated.
14. *E. cylindrica,* unsporulated.
15. *E. alabamensis,* unsporulated.
16. *E. alabamensis,* elongated specimen undergoing sporulation, showing characteristic parachute-shaped caps at ends of sporocysts preceding segmentation into sporozoites.
17. *E. bovis,* unsporulated.
18. *E. bukidnonensis,* unsporulated specimen showing characteristic thick wall.
19. *E. canadensis,* unsporulated specimen with regularly ellipsoidal shape.
20. *E. canadensis,* slightly tapered specimen undergoing sporulation.
21. *E. auburnensis,* smooth-walled specimen undergoing sporulation.
22. *E. auburnensis,* unsporulated specimen with heavily-mammillated wall.

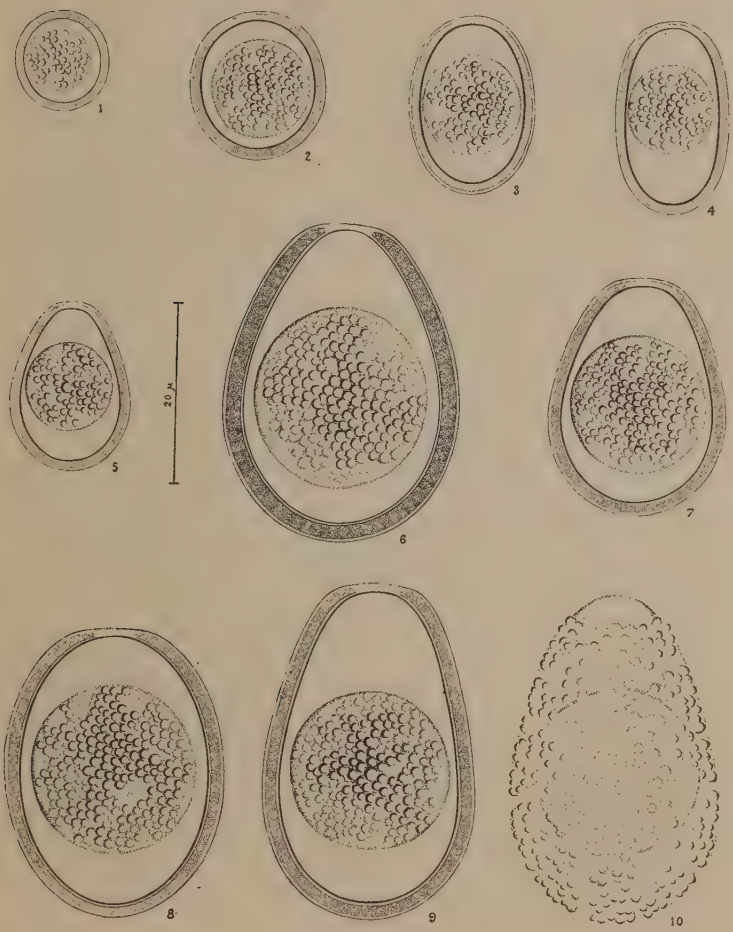

PLATE I

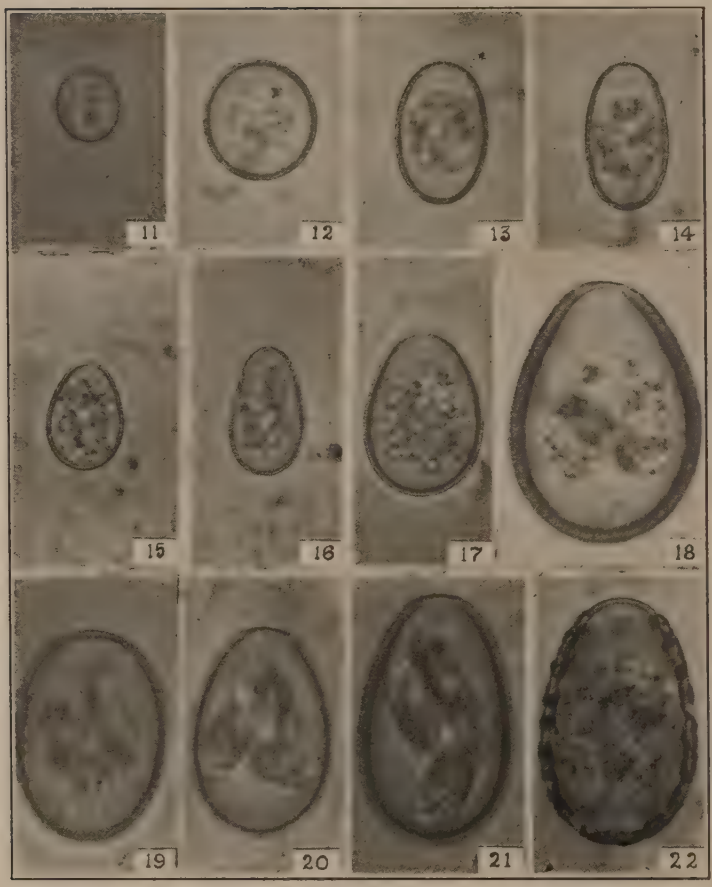

PLATE II

CORALLOBOTHRIUM PARVUM N. SP., A CESTODE FROM THE COMMON BULLHEAD, *AMEIURUS NEBULOSUS* LE SUEUR*

JOHN E. LARSH, JR.

Corallobothrium parvum n. sp. is a tapeworm found in the small intestine of bullheads, first taken in these fish from Black Lake, in the Douglas Lake region of Michigan, the summer of 1939. They were later found in bullheads from southern Illinois.

Fritsch (1886) set aside this genus to accommodate a species of cestode, *C. solidum,* from *Malapterurus electricus,* an electric catfish of Egypt. Fritsch chose this name, *Corallobothrium,* because he thought the scolex resembled an Oculina-like coral. Until the work of Riggenbach (1896), no other species was referred to this genus. In this work, Riggenbach gave the name *Corallobothrium lobosum* to a cestode from *Pimelodus pati,* a siluroid of Paraguay. However, Fuhrmann (1916), in redescribing this tapeworm, disclosed the fact that some of the genital organs were situated in the cortical parenchyma. This fact alone left Fuhrmann with the task of removing this worm from the genus *Corallobothrium,* since all proteocephalids have the entire genital arrangement confined to the medullary parenchyma. Therefore, Fuhrmann created a new genus for this worm, namely, *Rudolphiella.* Fuhrmann and Baer (1925) reduced *Rudolphiella* to synonymy and placed *Rudolphiella lobosum* Fuhrmann in the genus *Ephedrocephalus.* Woodland (1925, part II) proposed to delete such genera as *Corallobothrium, Choanoscolex, Acanthotaenia, Goezeela,* and *Gongesia,* since these groups had been set aside primarily on the basis of the character of the scolex. Woodland gives only secondary importance to this character. Space does not permit one to present evidence for and against the retention of this genus. However, on the basis of the arguments voiced by Essex (1927), Meggitt (1927), and Harwood (1933), and since there is as yet no reliable substitute I propose to follow Braun (1895), La Rue (1914), Fuhrmann (1916), Ward (1918), and other later writers in accepting the genus *Corallobothrium* on the basis of the unusual scolex and the new species described in this paper has been referred to that genus.

Corallobothrium parvum n. sp.

(Figs. 1–8)

Specific diagnosis: Tetraphyllidean cestode with characters of the family PROTEOCEPHALIDAE and the genus *Corallobothrium.* Length 3.2 mm to 4.2 mm;

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* Contribution from the University of Michigan Biological Station and the Zoological Laboratory of the University of Illinois. The writer is greatly indebted to Dr. Lyell J. Thomas for his guidance and helpful criticism in this work.

breadth 526 to 683 μ. Proglottids six to nine, anterior ones wider than long, posterior one longer than wide. Scolex globular, 582 to 631 μ in diameter, four suckers situated on the anterior surface surrounded by many irregular folds and lappets of tissue (Fig. 6); no rostellum; neither hooks nor spines, genital pores peripheral, irregularly alternating.

Ovary ventral, follicular. Vitelline ducts anastomose anterior to the ovary. Shell gland rosette-shaped, surrounding the oötype. Uterus branching with seven villiform diverticula. Seminal receptacle absent.

Male reproductive system dorsal to that of the female. From eighteen to twenty-five spherical to oblong testes in the medullary parenchyma. Cirrus pouch marginal, irregularly alternating in the anterior fifth of the proglottid, dorsal to the vagina and longitudinal excretory vessels. Vas deferens, at the level of the cirrus pouch, a compact mass of many coils. White colored eggs with three membranes, 18 to 26 μ in diameter, when mature. Procercoid in *Cyclops;* plerocercoid in the intestine of *Glaridichthys talcatus* and *Ameiurus nebulosus.*

Type host: Ameiurus nebulosus Le Sueur, the common bullhead.

Habitat: The small intestine.

Type locality: Douglas Lake, Cheboygan County, Michigan.

Type specimen: B. A. I. and U. S. Nat. Museum Helm. Coll. No. 36714.

EXTERNAL MORPHOLOGY

These tiny, milky-white cestodes are found attached to the upper end of the host's small intestine in the duodenal region (Fig. 1). Although the strobilization is not perfectly distinct, one is able to detect six or seven proglottids in the chain. Among more than one hundred adult specimens measured before and after fixation, 4.2 mm is the average length recorded. In these, the mature proglottids are about 736 μ long by 526 μ wide. The segments in the anterior portion are always wider than long, but proceeding posteriad the length gradually increases at the expense of the width. Thus the posterior proglottids are longer than wide.

The form of the scolex is highly variable owing to different states of contraction (Fig. 2). In living specimens, the size varies from 472 to 578 μ long by 582 to 631 μ wide. The four, strongly muscular suckers are directed anteriorly and are more or less concealed by the folds of the scolex. There is no rostellum or rudiment of a fifth sucker revealed in various sets of sagittal and transverse sections. The neck, as seen in sagittal sections, is about 65 to 83 μ long and 485 μ wide. It is not easily recognized in much contracted toto mounts.

The cuticula comprises the external body covering. Layers of longitudinal and circular muscles are present. The inner longitudinal muscle sheath is exceptionally well developed in the strobila (Fig. 4). These inner muscular layers make up the boundaries of the medullary parenchyma. The nervous system consists of a ring and two nerve trunks. The former is situated in the median region of the scolex. Arising from the lateral portion of the ring, two trunks pass off parallel to the ascending excretory vessel and follow a course along the inner margin of the longitudinal muscle layer. The excretory tubules are easily seen in sections of immature proglottids. There are four principal longitudinal

trunks which are located in the lateral regions of the medullary parenchyma almost parallel to the longitudinal nerve trunk of each side. In the scolex, these tubules interlock to form a lattice-like network.

INTERNAL MORPHOLOGY

A common genital atrium occurs on the lateral margin in the anterior fifth of the proglottid. For the most part, the character and arrangement of the reproductive organs is almost identical with that of other proteocephalids. The entire reproductive system lies within the medullary parenchyma, a constant character of the members of the family PROTEOCEPHALIDAE.

In the male system, the testes are observed to be varied in shape due to pressure exercised by surrounding structures (Fig. 4). The majority are elliptical and measure from 29 to 34 μ in diameter. From 18 to 25 are present in a single proglottid. They are present in a continuous field between the vitellaria, extending from the anterior margin of the proglottid posteriad to the level of the ovary. The vas deferens is prominent; and, at the level of the cirrus pouch, forms a compact mass of many coils that extend almost the entire distance between the vitellaria in the medullary layer. The cirrus pouch is elongate-oval when the cirrus is inverted. At this time, the pouch measures from 136 to 138 μ long by 45 to 48 μ in greatest diameter.

In the female system, the vagina opens into the genital sinus ventral to the cirrus. The position of the vagina at this level is almost always posterior to the cirrus pouch. From this level, the vagina passes laterally to an almost median position. From here, it proceeds posteriorly to the region of the genital complex (Fig. 7). The follicular ovary is present in a horizontal anchor arrangement and is situated in the posteriormost region of the proglottid. Along the median line, the vitelline ducts anastomose anterior to the ovary. The vitellaria are compact masses extending in two lateral rows from the anterior to the posterior margin of the proglottid. Surrounding the oötype is the so-called shell or Mehlis gland with its characteristic globular cells. The uterus, in mature and ripe proglottids, is composed of seven or more lateral pouches which give the entire proglottid a wrinkled appearance internally. This structure, in ripe proglottids, almost completely fills the inter-proglottidal space. It extends laterally to the vitellaria and from the anterior margin to near the level of the ovarian isthmus. It opens to the exterior through several uterine pores which fuse into a slit-like cavity in spent proglottids near the ventral median line (Fig. 1).

THE LIFE CYCLE

Observations of the Egg: After the tapeworms were removed from the small intestine, they were placed in tap water. This change in pres-

sure brought about an expulsion of thousands of eggs. The mature egg is rather small; the size of twenty-three in the first dish was from 18 to 28 μ in diameter (Fig. 8). The eggs are white and have three membranes. The onchosphere lies beneath the third membrane and may be seen extending and withdrawing its hooks.

The First Intermediate Host: A plankton net was used to collect various species of copepods from Douglas Lake. These were placed, a few at a time, in a watch glass that contained a small amount of water. A microscopic examination was made to determine whether they were parasite-free. The non-infected ones were introduced into Petri dishes with the infective tapeworm eggs. In a few minutes, it was observed that many *Cyclops* feasted on these eggs. Twice daily, these copepods were examined for evidence of infection. On the third day, it was observed that the onchosphere had gained access to the body cavity of several *Cyclops*. On the eighth day, the body cavity of *Cyclops prasinus* was found packed with procercoids (twelve in one case). These first larval forms measured, on the average, 342 μ long by 112 μ wide. Aside from their constant movement and the presence of calcareous bodies, there was not much detail to be detected (Fig. 5). The packed condition also made it difficult to define the individual boundaries.

The Second Intermediate Host: Small tropical fish, *Glaridichthys talcatus,* were used in an experiment to determine if these larval forms would go through another intermediate host. The infected *Cyclops* were placed in a finger bowl with these small fish. In a little while, the fish had ingested eleven *Cyclops*. Three days later, plerocercoid cysts were discovered in the intestinal mucosa and in the body cavity. On an average, these encysted forms were about 158 μ long by 189 μ wide. It is not known, as yet, whether this phase of the cycle is a necessary one or merely a storage place for the larval forms until they can be taken by the definitive host. Lack of material did not allow this determination. Until otherwise ascertained, however, it must be assumed that this phase is needed. Hence, it is called the second intermediate host phase in contrast with the unnecessary phase which is termed the auxiliary host phase.

The Definitive Host: Seven tropical fish, *Glaridichthys talcatus,* infected with plerocercoids, were placed in a small aquarium with twelve bullheads (about four inches long) which had been purposely starved for some time. The bullheads immediately feasted on these smaller fish. After four days, three bullheads were dissected. The intestine of each fish showed several plerocercoids (Fig. 3). Three of the remaining nine bullheads dissected three days later were found to be infected. The bullheads used in this experiment were taken from a collection of fifty, thirty-three of which were found by dissection to be uninfected. Of the seventeen bullheads remaining from the original collection of fifty, twelve

were selected for this experiment and were presumably uninfected; at least, an infection could be superimposed in this case. The plerocercoids recovered here were opaque, and the body resembled a cone. The calcareous bodies were less numerous than in the procercoid. Aside from this fact and the adult-like condition of the scolex, no other noteworthy facts were observed.

The cycle was thus experimentally completed in *about fifteen days.* From infective eggs to procercoids in the *Cyclops about eight days;* from procercoids into plerocercoids in the second intermediate host *about three days;* transfer of plerocercoids into the definitive host *about four days.*

Indications are that other new tapeworms of this interesting genus occur in bullheads that are found in the Douglas Lake region. The present research indicates that ample material will be available. Therefore, further research may provide additional data.

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Explanation of Plate

All figures are camera lucida drawings unless otherwise stated. The projected scale for Figs. 2, 3, 4, 5, 6, and 7 equals 0.03 mm; for Fig. 1 equals 0.20 mm; and for Fig. 8 equals 0.002 mm.

Fig. 1. Free hand drawing of the adult worm.

Fig. 2. Dorsal view, toto mount of scolex. A.F.A. fixation.

Fig. 3. Dorsal view of plerocercoid extracted from the intestine.

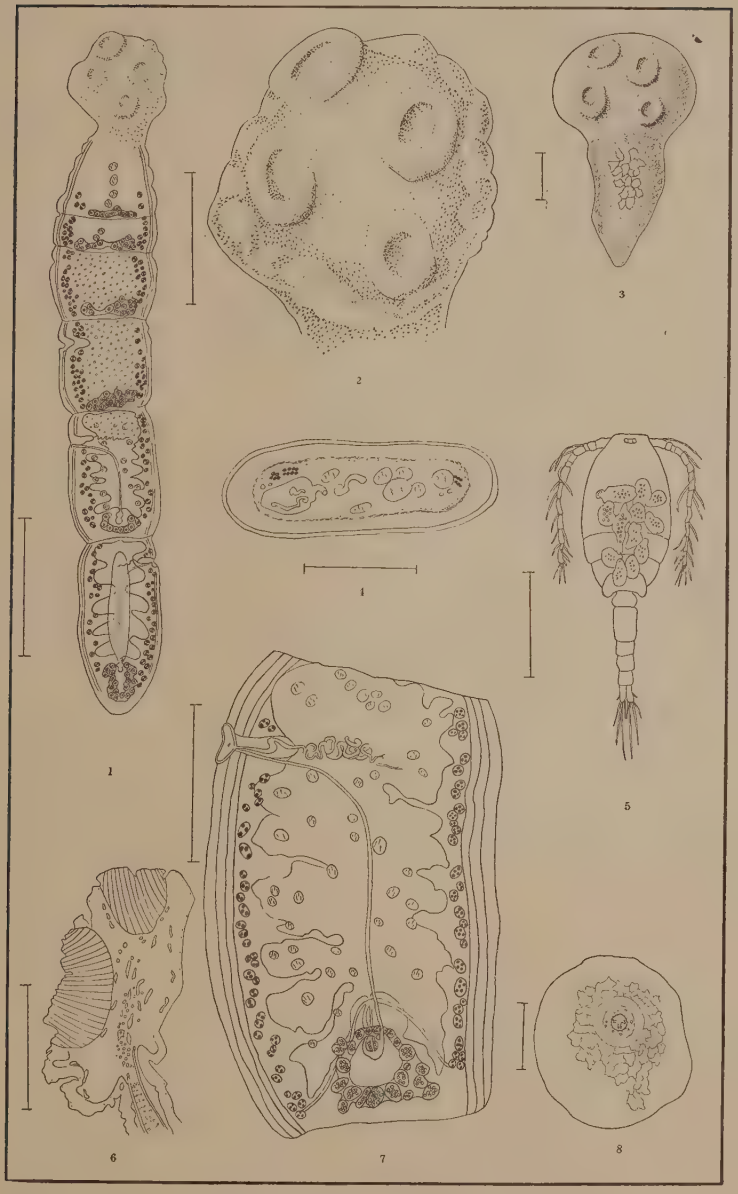
Fig. 4. Cross section through cirrus pouch.

Fig. 5. Free hand drawing showing dorsal view of *Cyclops* infected with procercoids.

Fig. 6. Sagittal section through scolex showing portions of the excretory ducts and the fringed margin of the scolex.

Fig. 7. Free hand drawing of mature proglottid, toto mount, ventral view.

Fig. 8. Free hand drawing of infective egg soon after laying.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DESCRIPTION AND EXTRAMAMMALIAN LIFE OF *CRENOSOMA MEPHITIDIS* N. SP. (NEMATODA), IN SKUNKS

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A *Crenosoma* was found in *Spilogale gracilis phenax* Merriam and *Mephitis occidentalis* Baird captured in San Francisco and Marin County, California. The parasites inhabit the bronchi below the bifurcation; some may be found on the mucous membrane of the trachea.

Crenosoma mephitidis n. sp.
(Figs. 1–2)

Male: 8 to 9 mm long and 0.30 to 0.35 mm wide. There are about 20 distinct cuticular folds over a region of about 1 mm of the body length. Parallel longitudinal ridges extend over the entire surface of the cuticle, but gradually decrease in distinctness toward the posterior end of the parasite. Esophagus club-shaped, 350 to 375 μ long and about 75 μ wide at its greatest diameter, being only half as wide at its junction with the intestine. A festoon of esophageal cells is inserted into the intestine. Excretory pore opens about 90 to 100 μ behind head region. Ventral to esophagus and intestine are two large cucumber-shaped cervical glands measuring over 1 mm in length. Intestine fairly straight tube, wider than the esophagus. Bursa well developed (Fig. 1), measuring outspread 300 μ. Width of body of the parasite above ventral rays 150 μ. Bursa notched at the ends of the ventral, posterolateral and dorsal rays. Rays springing from stout bases and well developed. Ventral rays only partially divided. Ventrolateral stouter and longer than the ventroventral. Externolateral closely situated to medio- and posterolateral, as is the externodorsal. Externolateral and externodorsal of similar appearance; both end near margin of bursa. Mediolateral and posterolateral divided about half their lengths. Dorsal simple. It shows at least 2 minute papillae distally. Spicules equal in size, not over 380 μ long. Viewed dorsoventrally they appear straight; laterally seen they are slightly bent proximally. Tapering distally they end in a small knob. Both spicules closely situated together, covered by a delicate cuticular sheath, strongly connected by a chitinized thorn with a bifurcated 90 μ long accessory piece.

Female: about 18 mm long and 0.6 to 0.7 mm wide. Cuticular folds extend over an area of 2.60 to 2.75 mm. Size, structure and accessories of esophagus similar in both sexes. Vulva opens about 1 mm above equator of body length. Opening of vulva simple retraction of cuticle without appendices. Vagina slightly chitinized, inserted at the middle of the kidney-shaped ejaculatory duct. Ovejector parallel to longitudinal axis of body; other parts of genital organs double as usual. Tail (Fig. 2) 140 to 150 μ long, pointed, 2 minute lateral papillae 20 μ distant from tip of tail. The thin-shelled, colorless eggs 72 μ in length and 36 μ in width. They contain fully developed first stage larvae.

Host: Spilogale gracilis phenax Merriam, and *Mephitis occidentalis* Baird.

Location: Bronchi.

Locality: San Francisco and Marin County, California.

Type specimens: Hooper Foundation, San Francisco.

Received for publication, August 6, 1940.

Comparing this *Crenosoma* with other known species in the tabulation given by Buckley (1, p. 236) there are differences noticeable. Its similarity, however, to *Crenosoma vulpis* is manifest. Differences between both are seen in the slightly larger size of the *Crenosoma* of the skunk, especially in the female, in the presence of cervical glands, and in the position of the anus closer to the tip of the tail. The rays extend nearer to the border of the velum, and this parasite is not strictly viviparous. Further investigations possibly may show that presence of cervical glands and deposition of embryonated eggs are generic in *Crenosoma*.

DEVELOPMENT OF INFECTIVE LARVAE

Larvae still enclosed in the eggshell become livelier as the egg moves to the stomach. The shell becomes softened and is extended and retracted by the movements of the larvae. The shell is finally dissolved without residue. Larvae, as a rule, are freed at their arrival in the small intestine. They are easily demonstrable in stools and they may be isolated by the filter method (2).

Newly hatched larvae (Fig. 3) measure alive 270 to 305 μ in length by a maximum width of 14 μ. The esophagus is 110 to 120 μ long and 6.5 μ wide near the posterior end. The genital primordium is situated at the middle of the intestine. The length of the pointed tail is about 35 μ.

Larvae may be kept alive in water for several weeks, if the temperature is below 15° C and putrefaction is strictly avoided. Dried on glass slides, a few larvae revived in water after 5 to 6 weeks.

As in the case of *Crenosoma vulpis* (3) a great variety of slugs and snails are found to serve as intermediate hosts. Infective stages could be raised in different species of *Limax*, *Agriolimax*, *Milax*, *Helix* and in *Epiphragmophora* at our disposal. The larvae are seen enclosed in nodules embedded in the foot of the mollusks, as well as in internal organs.

The infective larva is 525 to 560 μ long and 25 to 29 μ wide. In a larva (Fig. 4) 525 μ long the esophagus measured 210 μ. There seem to be two lips forming the anterior end. A small buccal capsule leads into the chitinized muscular part of the esophagus, which is 55 μ long. The glandular part, 150 μ long, shows no special bulb formation, becoming gradually wider nearing the junction with the intestine. The excretory pore opens 135 μ behind the anterior end. The width of the parasite at the junction is 25 μ, near the middle of the body it is 29 μ, from which it decreases gradually toward the anus. The tail measures 43 μ in length. The larva tapers less posteriorly than it does anteriorly and ends in a minute spine. The intestine is connected with the anus by a cuticular rectum 18 μ in length. The genital primordium is visible in the middle of the length of the intestine.

Formation of infective stages requires from 4 to 5 weeks. Two molts are observed during this development and as usual none of the sheaths is shed. There is evidence that larvae with two sheaths are not necessarily infective, as demonstrated by the following observation: Tissues of infected intermediate hosts were exposed to artificial digestion. Investigation of the fluid about half an hour later disclosed the presence of freely moving unsheathed larvae, apparently representing fully developed infective stages. There were, however, also dead larvae encountered enclosed in two sheaths. The latter seemingly were not able to withstand digestion, having not yet attained their full development. This simple method of determination of the viability of third stage larvae may occasionally be useful in place of tedious feeding experiments.

The Pacific garter snake, *Thamnophis sirtalis infernalis* Blainville, was found to serve as a natural auxiliary host. Parasitic tubercles, even visible to the unaided eye, may be seen covering the outside of the stomach and of the intestine. Microscopic investigation reveals their presence in even larger numbers in and under the mucous membrane of both organs. Few nodules only are encountered in the body cavity. No alteration of the parasites was seen in a snake kept in captivity for 12 months. Practically no calcified nodules were found in all the 38 snakes naturally infected. It is likely that the difference in localization of the parasitic cysts is caused chiefly by the increasing tissue resistance built up with the progressing age of the snakes. Other poikilothermous animals, namely frogs, toads and lizards, could be artificially infected. The larvae were found chiefly in and under the mucous membrane of the stomach. The intestine itself contained the parasites in lesser numbers.

Skunks kept in the animal house lost infections after several months, but infections of *Crenosoma mephitidis* and of *Skrjabingylus chitwoodorum* still persist in skunks living in pens outdoors since 1935. This is explained by the possibility of reinfections in the pens.

Control of *Crenosoma* has to take in account the possibility of spread of the parasite by poikilothermous animals. This may be of concern in combating *Crenosoma vulpis* on fox farms.

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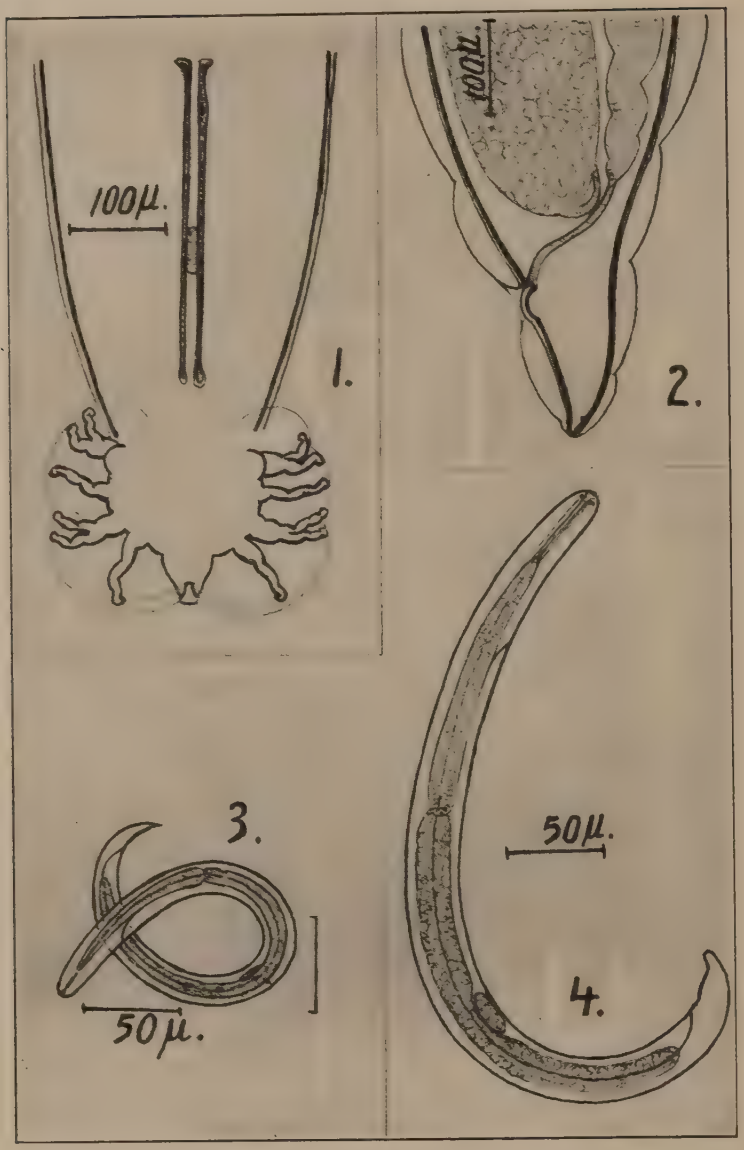

Crenosoma mephitidis n. sp.
1. Posterior end of male.
2. Posterior end of female.
3. First stage larva.
4. Third stage larva.

EXTRAMAMMALIAN PHASE OF *PHYSALOPTERA MAXILLARIS* MOLIN, 1860 (NEMATODA)

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Freshly deposited eggs contain, as already known, a fully developed larva which does not hatch outside the intermediate host. No opercula are visible on the eggs. The vitelline membrane, however, becomes dissolved at the poles of the egg under the influence of digestive juices and calottes of the thick outer eggshell consequently become detached. The middle part of the eggshell, shaped like a barrel with slightly fringed edges, remains unaltered. This procedure takes place in fertile eggs as well as in sterile ones. The larva takes no part in liberating itself.

Living first stage larva are from 275 to 310 μ long and about 15 μ wide. Slightly attenuated anteriorly they end in a small cap-like head structure. Posteriorly they taper slowly but continuously to end in a pointed simple tail. The esophagus is 110 to 130 μ long. The excretory pore opens 75 to 90 μ behind the anterior end of the body. Beneath the pore a transparent vesicula may be seen. The tail is about 35 to 50 μ long (Fig. 1).

Further development of the larva is similar to that of *Physaloptera turgida* (1). The cockroach, *Blatella germanica,* was used as intermediate host. To keep and to raise cockroaches cages or containers may be used and water may be provided as described in Galtsoff et al (2). A piece of crumbled paper placed into the containers serves as hiding place. Dry sugar is given as only food. This arrangement prevents mold formation, requires a minimum of care, and provides satisfactory conditions for parasitic experiments. Moldy water or food may develop an aspergillosis in the cockroaches, which causes the inner organs, together with the parasites present, to undergo dry necrosis.

Infective larval stages are attained in from 4 to 6 weeks. Their final sizes vary from 1.8 to almost 3 mm in length by a maximum width of 120 μ. These differences are due only in part to age and sex. The following observation may explain part of the phenomenon: Esophagus and intestine appear usually as a fairly straight tube. Occasionally, however, the cuticle expands insufficiently. Consequently, the esophagus is bent S-shape and the intestine folded. Such larvae, of course, remain in measurements below their actual sizes. One or more larvae may be found enclosed in colorless cysts according to the severity of the infec-

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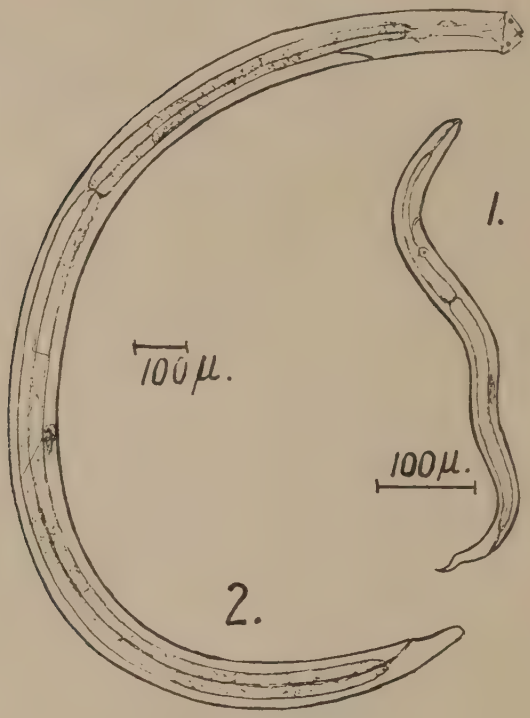

Physaloptera maxillaris

1. Freed first stage larva.
2. Third stage larva.

tion. Some of the cysts may show a golden-brownish color similar to that of the cuticle of the cockroach, with or without destruction of the enclosed larva. In lungworm larvae in snails, where we observed similar colorations occasionally, pigmentation may be observed beginning in the larval sheath prior to or in the process of molting.

Larvae fed to larvae of *Tenebrio molitor* were found six weeks later in the abdominal cavity. They had died without further development and were intensely brownish colored. Such pigmentations as observed in *Blatella* and *Tenebrio* were absent in the natural intermediary host *Stenopelmatus longispina*, Brunner. It is concluded that pigmented incrustations result from host tissue reactions following invasion of less suitable intermediate hosts by parasites.

Third stage larvae of *Physaloptera* (Fig. 2) are readily distinguishable from similar stages of other nematodes in cockroaches by the characteristic formation of their head parts. As in adult *Physaloptera* these

are already triangular in outline. The delicate structure of two lips with teeth, papillae, and even amphids are already discernible. In a living larva, 2.13 mm. long with a maximum width near the esophageal junction of 100 μ the gonesophagus was 170 μ long, the postesophagus 670 μ, the intestine 1.13 mm. the tail 160 μ. The distance from the anterior end to the nerve-ring measured 150 μ, to the excretory pore 180 μ. The horseshoe-shaped genital primordium was situated just anterior to the middle of the intestine. The tail ended bluntly.

No parasites were found on examination 6 weeks after having fed infected cockroaches to rats, dogs and guinea pigs. Adult stages of *Protospirura muris*, on the other hand, were obtained under similar conditions in guinea pigs, and subsequent infections of intermediate and of final hosts could be carried out.

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EXTRAMAMMALIAN PHASE OF *SKRJABINGYLUS CHITWOODORUM* (NEMATODA)

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This nematode has been reported and described recently by Hill (1) as a parasite of *Mephitis mesomelas mesomelas*. Hill gives the size of the female parasite as 29 mm by 660 μ. We found fully grown specimens 42 mm long and 850 μ wide in infections of *Spilogale gracilis phenax* Merriam and *Mephitis occidentalis* Baird, observed in the bay region of San Francisco, California. Collection of the parasites is facilitated by resecting the roof of the frontal sinus—their natural habitat—and then submerging the skull in water. Most of the nematodes will voluntarily emigrate into the water under this condition. The nematodes withstand bursting by osmosis for several days. The larvae in the uterus remained alive and freely moving during this time. Larvae dried on blotting-paper did not revive after two days.

First stage larvae are discharged with the feces. In post mortems they may be recovered from the inner surfaces of the entire respiratory and digestive tract. No expulsion of larvae by nose was seen. Demonstration and collection of these and similar larvae from stools may be facilitated by the use of the following method: Feces are comminuted in water and strained into a glass jar. Its top is now covered with three to four layers of gauze. A funnel closed on its end with an adjustable glass tube is filled with water to receive the inverted glass jar. After standing undisturbed for a few hours the larvae present will collect in the adjustable glass tube in a fairly clean condition (2).

Larvae measured alive (Fig. 1) were 410 to 450 μ long with a width of 13 μ to 15 μ at the esophageal junction. The larva tapers continuously and not abruptly behind the tail to end in a short spine. Neither stained nor unstained specimens revealed distinctive features of the head parts. Granules partly cover internal structures of the larva. The esophagus is 160 to 180 μ long, widening distally to a small bulb about 10 μ in width. The excretory pore opens approximately 100 μ distant from the head region, just below the nerve ring. The genital primordium is situated near the middle of the intestine. The tail measures about 43 μ in length. The larvae are livelier and taller than those of *Crenosoma*.

Third stage larvae developed in all the slugs and snails available at the time of the experiments, namely: *Limax maximus, L. cinereus, L.*

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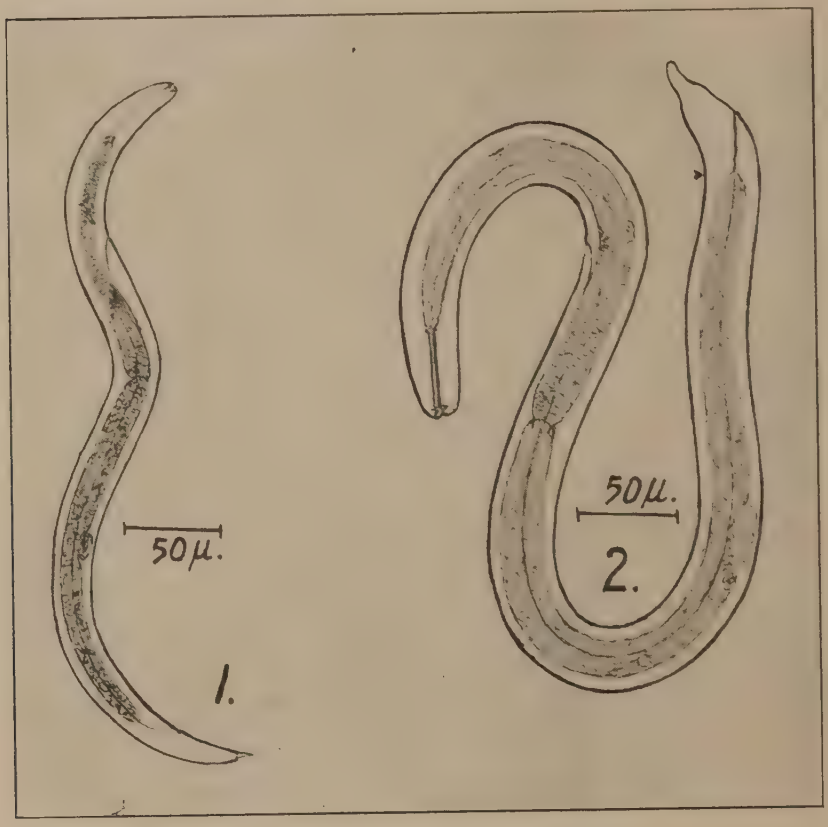
flavus, *L. niger*, *Agriolimax agrestis* and *Milax* sp., while *Epiphragmophora* and *Helix pomatia* seemingly were less favorable hosts. The larvae are enclosed in tubercles situated mostly in inner organs of the mollusks. The foot region seems to be a less favored site of invasion. Infection seemingly takes place by active invasion of the foot as well as



Skrjabingylus chitwoodorum

1. First stage larva.
2. Third stage larva.

following intake of food. The latter conclusion is based on the observation that the intestinal wall itself occasionally becomes heavily infected. The larvae often liberate themselves during investigations, abandoning nodules and sheaths. Once freed they show great agility. Preliminary experiments indicate that the route of immigration in final hosts simply

follows the nasal passages. Almost instant liberation and great activity of the larvae are necessary to achieve this goal before the infected food has been swallowed. The thorough mastication of the food noted in skunks facilitates freeing of the larvae.

The larvae are considerably longer and wider than those of *Crenosoma* (Fig. 2). They measure (alive) 830 to 850 μ in length, with a maximum width of 36 μ behind the esophageal junction. The esophagus, about 290 μ long, is club-shaped, becoming only moderately wider distally, without presence of a distinct bulb. The excretory pore opens approximately 110 μ behind the head region. The parasite is more attenuated anteriorly than it is posteriorly. The tail is only 40 μ long. The genital primordium is situated on the intestine near its middle measuring about 30 μ in length. The straight intestinal tube is connected with the anus as usual by a short cuticular rectum.

No adult stages could be raised in experiments on four guinea pigs, two ferrets, three dogs and three cats. In mice and rats some of the larvae could be recovered from the wall of the stomach and its mesenteries. The larvae disintegrated, however, during the second or third week.

Natural infection by third stage larvae was observed in the Pacific garter snake, *Thamnophis sirtalis infernalis* (Blainville). Localization of the larvae was similar to that of *Crenosoma*. Frogs could be artificially infected. Poikilothermous animals therefore serve as intermediate hosts, and rats and mice may serve occasionally as accidental transitory carriers of infective stages. For identification of the snake I am indebted to Dr. C. M. Wheeler. From autopsies it was learned that the main food of the Pacific garter snake consists of slugs. *Limax flavus*, the largest and most common slug of the San Francisco region often formed its exclusive stomach content.

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THE SPECIFIC STATUS OF *MONILIFORMIS* (ACANTHOCEPHALA) OF TEXAS RATS, AND A REVIEW OF THE SPECIES OF THIS GENUS IN THE WESTERN HEMISPHERE

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The writer (1921) reported the common occurrence of a species of *Moniliformis* in various species of *Rattus,* particularly *R. alexandrinus,* in Houston, Texas and expressed uncertainty as to the relationships of these worms to various previously described members of the genus, both in this country and in Europe. Van Cleave (1925), after examination of some of the Texas forms and comparison of them with specimens from various other parts of the world, came to the conclusion that they belonged to the type species, *M. moniliformis* (Bremser, 1811), and that there was only one other valid species in the genus, *M. clarki* (Ward, 1917) from American squirrels and a mole. Meyer (1933) reviewed the genus again and recognized no less than nine species. He considered the Texas form distinct and named it *M. dubius,* and also considered a form from Brazilian rats, reported by Travassos (1917), as distinct and named it *M. travassosi.* Another form, obtained from the droppings of a Brazilian vampire he also recognized as a separate species, *M. convolutus.*

Since the Texas form has been extensively studied by the writer and his students since 1921, and since there were certain errors in the original account of it which have influenced Meyer in his taxonomic conclusions, and have been widely quoted by other authors, it is desirable to amend the account and bring it up to date, and to discuss the specific status of this and other American forms.

The body length of mature female worms was given in 1921 as 140 to 270 mm and of mature males as 30 to 45 mm. Van Cleave (1925) made a point of the body size in distinguishing *M. moniliformis* from the smaller *M. clarki.* A study of the host-parasite relations of the Texas worms by Burlingame and Chandler (1940) showed that body size is enormously influenced by the age of the worms, the number of worms harbored, the presence of worms from a prior infection, the position of the worms in the intestine of the host, and the host itself, even within a single species (albino laboratory rats). The size of sexually mature worms may vary from 60 mm for females and 30 mm for males in 7-week-old worms in secondary infections, to 320 mm for female and 145 mm for males in 6-month-old light primary infections. Unless the history of an infection is

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known, therefore, body size cannot be given much weight in separating species.

It is otherwise with the size and structure of the proboscis. This organ is fully developed in the infective larva before infection of the final host, and so is not influenced by the factors which determine body size. Some variation may occur due to contraction, and some invagination of the tip of the proboscis may be overlooked, but in specimens with the proboscis fully extended the variations due to contraction are slight. In measurements of a large number of the Texas worms, including both infective larvae from the body cavity of roaches and adult worms from the intestines of wild rats and of experimentally infected albino rats, the length of the proboscis varies from 550 to 640 μ; it is occasionally almost cylindrical in larvae, but in adults is always somewhat spindle-shaped, with the maximum diameter about one-third to one-half the distance from apex to base. Measurements of proboscis diameter in numerous specimens fall within the following limits: near apex, behind first row of hooks, 160 to 175 μ; maximum diameter, 190 to 240 μ; base, 160 to 185 μ.

The number of longitudinal and transverse rows of hooks is sometimes difficult to determine, since the arrangement is not quite regular. There are, however, in all specimens I have examined, larva or adult, 12, 13, or 14 longitudinal rows, with usually 10 or 11 hooks in each row, rarely 9 or 12, making a total of about 125 to 145 hooks. Both my 1921 description and Van Cleave's 1925 description are erroneous with respect to this particular character, although Van Cleave's figure is correct.

The size of the eggs, if they are fully mature, varies between 112 and 125 μ in length and between 55 and 62 μ in diameter. The thick inner shell measures 85 to 90 μ by 36 to 38 μ, and the embryo itself, enclosed in the egg, 78 to 85 by 28 to 30 μ.

Some preliminary attempts (Chandler, 1921) to infect cockroaches were reported negative, but since then we have had no difficulty in obtaining development in *Periplaneta americana*, and find a high percentage of naturally infected roaches in places where infected rats are known to occur. This coincides with Travassos' (1917) observations in Brazil, and it is probable that the larvae described by Southwell (1922) from roaches from Gold Coast, Africa, belong to this species.

If the characters of the proboscis and eggs of this form are compared with those given for the type species as determined by Meyer (1933) for some of Bremser's original material, the following differences are noted: (1) the proboscis is much larger, and is spindle-shaped rather than club-shaped; (2) there are 10 or 11 instead of 7 or 8 hooks in each of the 12 to 14 longitudinal rows; (3) the hooks are larger and do not gradually diminish posteriorly, although those near the base of the proboscis are smaller than the others; (4) the dimensions of the ripe eggs are from 1½ to 2 times greater.

There can be little question that these differences are of specific value. Since the Texas form is also distinct from *M. clarki,* which more closely resembles *M. moniliformis* than it does our worm, and since it does not appear to be specifically identical with any of the other forms described prior to 1933, Meyer's name *dubius* appears to be valid. There are, however, no specific points of difference, as Meyer thought there were, between this worm and the one described from rats in Brazil by Travassos (1917), so *M. travassosi* Meyer, 1933, is considered a synonym of *dubius. M. dubius* has also been reported by Yamaguti and Miyata (1938) from rats on ships in Japan. Tubangui's (1931) description of *Moniliformis* from *Rattus norvegicus* in the Philippines leaves little room for doubt that he also was dealing with *M. dubius.* The *Moniliformis* recorded from *Rattus* spp. in Sydney, Australia (Johnston, 1918), Canton, China (Chen, 1933), Washington, D. C. (Price and Chitwood, 1930), and Baltimore, Md. (Luttermoser, 1936), all recorded as *M. moniliformis,* are probably also *M. dubius.* This species appears to have a world-wide distribution, having been spread by its cosmopolitan, sea-going intermediate and definitive hosts, whereas the other species may have much more restricted ranges.

It is probable that *clarki* is a valid species, although in many respects it closely resembles *moniliformis*; it has a more slender proboscis and a larger number of hooks, according to Van Cleave's figure. Meyer's *convolutus* is in most respects very close to *dubius* but differs in that the proboscis hooks have forked roots (see Meyer, 1931, fig. 250).

Sandground (1926) reported the presence of juvenile forms of *Moniliformis* in toads and lizards in Central America. Sandground assumed that these were incidental parasites but that they had taken up a truly parasitic existence, since many were firmly attached to the walls of the intestine. He remarked that the worms had attained a stage considerably in advance of those previously described from cysts of insects, but this is only because fully developed larvae had not been described up to that time. The photomicrograph of a larva of *M. dubius* from a cockroach in Burlingame and Chandler (1941) and the drawing of it in Chandler (1921) represent a larva in the same stage of development as the male larva figured by Sandground. When larvae of *M. dubius* were fed to toads in our laboratory, however, no temporary attachment of the parasites occurred, so it is possible that the toads and lizards may have something more than an accidental relationship to some Central American species of the genus.

Although Sandground referred these young worms to the species *moniliformis,* it is evident that they cannot belong to that species, since the proboscis hooks are of different shape, size and arrangement, and the proboscis more slender. These characters also distinguish it from both

clarki and *dubius*. It will probably prove to belong to a new species of which the adults have not been found.

In summary the genus *Moniliformis* is represented in the Western Hemisphere by the following species:

M. clarki, in *Sciurus*, *Citellus* and *Scalopus*, in Midwestern States of North America.

M. dubius (syn. *M. travassosi*) in *Rattus* spp., cosmopolitan.

M. convolutus, in *Vampyrus*, in Brazil.

M. sp., juvenile, in toads and lizards, in Central America.

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AVIAN TOXOPLASMOSIS WITH INVASION OF THE ERYTHROCYTES[1]

REGINALD D. MANWELL

Toxoplasma is a genus of parasites about which very little is known. Wenyon (1926) groups them with several other genera as "parasites of doubtful nature" and Sabin and Olitsky (1937) speak of the "as yet ill-defined group of Protozoa called *Toxoplasma*." A few authors questioned, at least until recently, the existence of the group at all. At present however more attention is being given *Toxoplasma*, partly because it has been shown that parasites belonging to this genus may cause encephalomyelitis in man (Wolf, Cohen and Paige, 1939) and partly because the unpigmented or exoerythrocytic stages of malaria may bear a considerable resemblance to these forms, so that there has been some question as to whether the two stages of malaria found in the vertebrate host did not represent a mixed infection of malaria and *Toxoplasma*.

The usual definition of *Toxoplasma* states that it is a genus of intracellular parasites, occurring in various types of leucocytes, in the body fluids, and even in other types of tissue, notably in the endothelium. They may be found in large numbers in various organs, particularly in the liver, spleen, bone marrow, lungs, kidneys and brain. The parasites themselves are small, and usually crescent-shaped. The accepted mode of reproduction is binary fission, although schizogony has also been claimed to occur.[2]

In a recent paper Sabin (1939) suggests that "the capacity to multiply and to produce disease in a variety of hosts, including mammals and birds, must, in accord with the conclusions of Aragao (1933), be regarded as the chief taxonomic characteristics of the group. Morphology as the only guide can be misleading and confusing. . . ." But it seems to the author that to make the absence of a strong host-specificity the chief characteristic of a genus only adds to the confusion, for this is certainly a relative matter. It is surely conceivable that different species may exist in the genus, and that these are likely to vary in the degree of host-specificity they exhibit. For these reasons it seems better to base the identification of the avian parasites which have been classed as *Toxoplasma* on morphology than to regard them as something else because transmission to other hosts has not

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[2] Raffaele (1932, Riv. Malariol. 11) describes schizogony in avian toxoplasmosis, and figures a number of stages which appear to form parts of a rather complex life-cycle. Although it seems certain that he was dealing with parasites which others have called *Toxoplasma* it is clear that they were in fact different, for binary fission was apparently not observed.

yet been accomplished. The point may readily be conceded that as more knowledge of this group accumulates it may become desirable to change their taxonomic classification, even to the extent of regarding them as something other than protozoa.

The present note is concerned chiefly with an infection with *Toxoplasma* which was recently seen in an English sparrow, and which was unique in that invasion of the red cells occurred on a considerable scale. The diagnosis was made on the basis of the morphology of the parasites and their distribution in the organs. Neither any thing seen in the case itself, nor the results of subinoculation into canaries gave any reason to think the infection might have been mixed. The fact that the bird was only a fledgeling, not more than three or four weeks old, makes it still less likely that more than one species of parasite was concerned. It was also clearly an acute infection, and the death of the bird two or three hours after being brought into the laboratory in a comatose condition suggests that this disease may be one of importance in nature, particularly in young birds. We have also observed many infections of toxoplasmosis among adult English sparrows, among which it seems to spread rapidly after they are brought into the laboratory and kept in relatively close quarters. Not infrequently the disease proves fatal, but there are often chronic cases.

Autopsy of the bird showed a very dark and much enlarged liver, and a spleen of similar appearance. The latter looked much as it often does in an acute case of malaria. The volume was approximately 450 cmm, perhaps 20 times the normal size. Other organs were negative. Smears of different organs did not show large numbers of parasites except in the liver and spleen, where they were extremely numerous. No pigment was observed, a fact which is further evidence that there was no malaria present.

The most interesting observation in connection with the present infection was the occurrence of the parasites within the red cells. In this situation they resembled malaria plasmodia markedly except that within the host cell the crescent shape was obvious, and pigment was lacking. In a few cases there were small granules which could have been mistaken for pigment (in Fig. 1, the arrow indicates such a granule). It was at first thought that the infection was either one of malaria, or a mixed infection of malaria and *Toxoplasma*. Examination of the organs showed that neither of these possibilities could be true, and despite hours of searching no parasites could be found in the blood (except in the leucocytes, or free) which were undergoing reproduction, or anything resembling schizogony. The staining reaction also differed from that seen in malaria in that it was more intense when Giemsa was used.

The microphotographs in the accompanying plate show parasites in different situations or stages. Figs. 1 and 2 depict forms in erythrocytes.

The question might arise as to whether these parasites were actually in the cells, as they appear to be, or whether perhaps they were below or above the cell. It cannot be affirmed that they were in the cell and not on the surface, but they seemed as truly in or on the erythrocyte as are malaria plasmodia. This is indicated because they were more frequently found in such situations than chance alone would seem to justify, and especially since all parasites seen in red cells were in the cytoplasm only. Their outlines coincided with the cytoplasmic margin of the host cell, and none of the forms appeared to overlap the chromatin. If their location resulted from chance alone, it is clear that few would occur in situations which so definitely suggested parasitism.

A further interesting observation was apparent schizogony, though no forms were seen in which this process had advanced far. Figs. 3 and 4 show two such parasites, and Figs. 6, 7, and 9 three groups of young forms which suggest origin by schizogony. However, they may also have come from a single disintegrated host cell in which reproduction was by binary fission, and in the liver and spleen no mode of reproduction other than binary fission was observed. It is possible, in view of the occurrence of free forms in the blood, and such forms as those figured which have just been mentioned, that reproduction may occur in the plasma as well as in host cells, either by binary fission or, as just suggested, exceptionally by schizogony.

Although it seemed clear that there was no malaria present, five canaries were inoculated to make doubly sure, and also to test further the possibility that *Toxoplasma* could be transmitted in this way if the dose was heavy enough. One of the five birds was inoculated intravenously with heart blood, two with an emulsion of splenic tissue, and two with a similar emulsion of liver tissue. In all cases the tissue was mixed with isotonic saline citrate solution. After inoculation the birds were followed by making blood smears every day or (after the first ten days) every two or three days. At death each was autopsied and organ smears examined. The results were completely negative as far as the possibility of malaria was concerned.

Of the five inoculated birds, two died within three days of the date of inoculation. The cause of death was uncertain, but it did not appear likely that it was due to *Toxoplasma,* unless in some way the bird was unusually sensitive to the organisms. One of these birds had received a massive injection of liver tissue which was very heavily infected with parasites, and the other received an emulsion of lung. The latter contained a moderate number of parasites, though fewer than the liver.

Two of the other three birds survived for about three weeks, and died apparently of a bacterial infection, presumably acquired from the injection. Both also showed *Toxoplasma,* but the infection was light and could

hardly have been responsible for their death. In one case a single parasite was seen, which in this instance was in the spleen; in the other there were scattered parasites in the lung and liver. The third bird is still alive and apparently in excellent health.

The question arises as to whether the two birds which showed *Toxoplasma* owed their infections to inoculation from the sparrow, or whether they might have already been infected. Herman (1937) reports a series of attempts to infect canaries from sparrows carrying *Toxoplasma,* all of which were negative. Canaries inoculated from sparrows infected both with malaria and *Toxoplasma* in the author's laboratory at various times have never appeared to harbor anything other than the malaria plasmodia afterward. The two birds just referred to above would, however, probably have continued to appear uninfected had autopsies not been made and organ smears examined. There is, therefore, the possibility that in the canary *Toxoplasma* does not ordinarily cause more than a mild, and transitory infection. It is true that Wolfson (1937) reported a number of successful transfers of *Toxoplasma* by inoculation of infected tissue from a canary infected with it to other canaries, and in her experience all successful transfers resulted fatally. Since these birds were also infected with *Plasmodium cathemerium,* however, and since this species exhibits exoerythrocytic schizogony, which stages at that time she regarded as "*Toxoplasma*-like parasites" (Hegner and Wolfson, 1938), it is possible that these infections were not true *Toxoplasma.*

There is another possibility, viz, that canaries are quite commonly infected with *Toxoplasma* when secured from the breeders, or after being kept in the laboratory for a time. Such infection, if mild, would escape notice since it is rather exceptional to see infected cells in the blood, but it might be sufficient to protect the birds against further infection. The evidence for such an assumption is the frequency with which bodies are found in the lungs, sometimes free, and sometimes within mononuclear cells, which bear a considerable resemblance to *Toxoplasma.* Kikuth has referred to them as "Einschlüsse" (Kikuth, 1937; Kikuth and Mudrow, 1938) and the present author has called them "x" bodies (Manwell, 1939). They have the appearance of parasites, and although they do not look exactly like the usual avian type of *Toxoplasma,* they may well be related organisms if not another stage of the same parasite. Kikuth and Mudrow show a colored figure (Fig. 6) and a photomicrograph (Fig. 10) is given by Manwell (1938). Apparently no one has ventured to make any definite suggestion as to the real significance of these bodies, although they have been mentioned by others. They have been seen in both healthy and malarious canaries, and in wild birds.

SUMMARY

An infection of toxoplasmosis in a young English sparrow is reported

in which invasion of the erythrocytes was observed on a considerable scale. Since the bird was very young and since subinoculation of blood and organ tissue into canaries failed to reveal any evidence of mixed infection, it is believed that the case was one of infection of *Toxoplasma* alone. The fact that the parasites occurred frequently in the red cells is of considerable interest since it has heretofore been regarded as typically a parasite of mononuclears, and of other types of phagocytic cells. A few forms were seen which were apparently undergoing schizogony, which it has been often thought does not occur in *Toxoplasma*. Two of the five birds inoculated with *Toxoplasma*-infected material (blood in one case, and spleen in the other) showed scattered parasites at autopsy, but died of other causes.

Reasons are suggested for believing that this may not have been a case of genuine transfer, and which may explain the failure of others to secure such transmission.

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EXPLANATION OF PLATE

FIGS. 1 and 2. Erythrocytes infected with *Toxoplasma*.

FIG. 3. A large macrophage containing what appears to be a schizont.

FIG. 4. A similar schizont free in the blood.

FIG. 5. Numerous free forms such as this were observed in the blood smear. Note the typical crescent-like shape.

FIGS. 6 and 7. Groups of parasites like this were observed in a number of cases in the blood, and suggest origin from schizogony, although they may perhaps have come from a single multiply-infected cell.

FIG. 8. A lymphocyte showing the typical notched nucleus of such cells when infected with *Toxoplasma*.

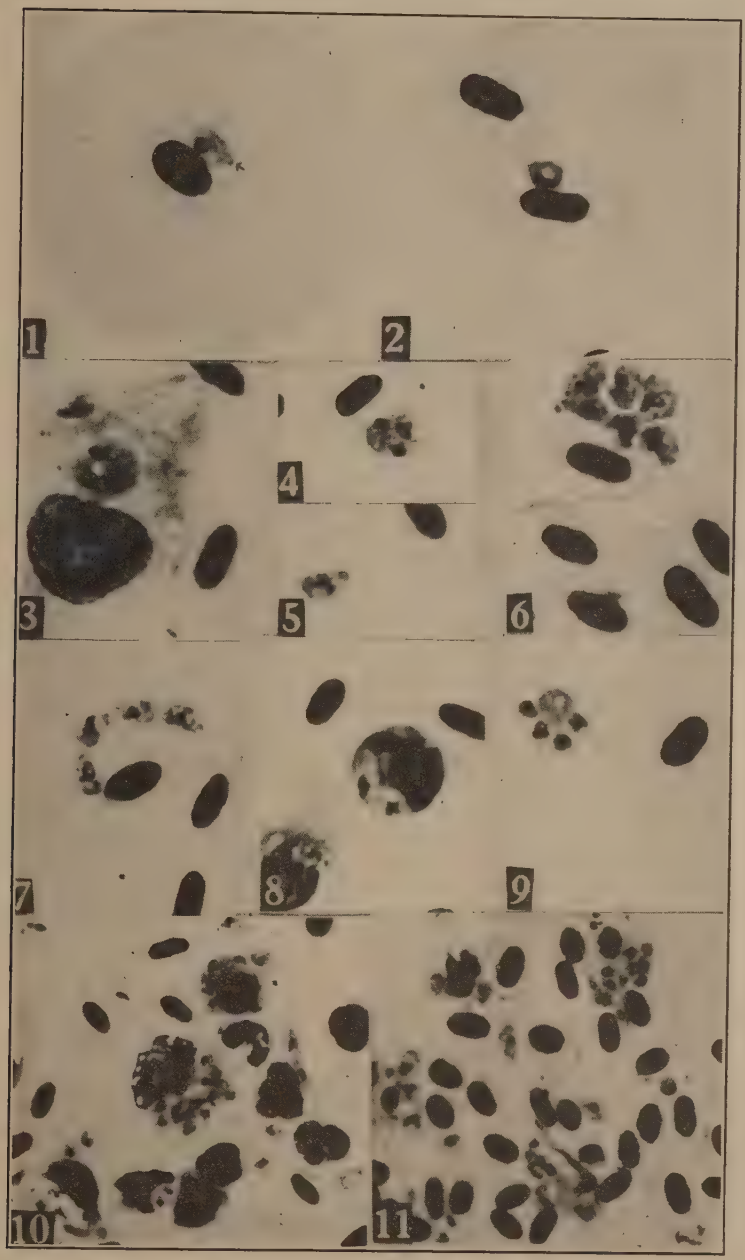
FIG. 9. A group of parasites similar to those shown in Figs. 6 and 7.

FIG. 10. From a liver smear. This figure and the one which follows show how numerous parasites were in these organs.

FIG. 11. From a spleen smear.

(Magnification 2000×, except in Figs. 10 and 11, in which it is 1200×.)

Microphotographs by Miss Stella Zimmer of the Department of Photography, Syracuse University Medical School.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THE TREMATODE GENUS *OTODISTOMUM* IN NORTH AMERICA*

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Otodistomum is a genus of digenetic trematodes (AZYGIIDAE) which is widely distributed in elasmobranch fishes. The genus has long been known to occur in rays of both the Atlantic and Pacific coasts of North America, but the status of the species involved has been under discussion for some time. Representative collections from *Raja stabuliforis* from the Isles of Shoals region off the New Hampshire coast and from *Raja binoculata* from Pacific Grove, California, offered opportunity to restudy the characters which have been advanced by earlier workers for recognition of species and varieties of *Otodistomum* in North America.

Stafford proposed the generic name *Otodistomum* in 1904 for trematodes which he identified as *Otodistomum veliporum* (Creplin) from a barn-door skate of Canadian Atlantic waters. Odhner (1911) called attention to the fact that the material which Stafford and several other workers had identified as *O. veliporum* was, according to his interpretation, a distinct species which von Beneden (1871) had named *Distomum cestoides*.

Manter (1926) reviewed the literature and on the basis of a carefully worked out analysis on limited collections from Alaska and Maine concluded that both *O. veliporum* (Creplin) and *O. cestoides* (van Beneden) occur in the North American fauna. After a review of the characteristics of these two species as given in the studies of European investigators, Manter expressed the belief that dimensions of the uterine eggs were about the only significant differences available for separating the two lots of material with which he was dealing, and which he assumed to represent *O. cestoides* and *O. veliporum*. For the Pacific forms, which he identified as *O. veliporum*, he measured 50 eggs finding an average length of 85.5 μ while his measurement for *O. cestoides* from the Maine coast gave a range of 65 to 72 μ for egg length with an average of 69.4 μ. In support of his findings on egg size as a basis for diagnosis he stated (page 41): "This difference is real, constant, and significant. In no case did the egg size overlap between the two species." In the same paper (1926: 57) Manter summarized application of his taxonomic consideration of the two species of *Otodistomum* in the following words: "The egg size is the most certain

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* Contributions from the Zoological Laboratry of the University of Illinois, No. 580, and the Isles of Shoals Marine Zoological Laboratory of the University of New Hampshire.

distinction between them." In support of Manter's conclusions, stand the earlier observations of Odhner (1911) who found *O. cestoides* eggs 65 to 72 μ by 43 μ in diameter and *O. veliporum* eggs about 86 μ long. Differences of this sort are not available for differentiating the two species in the original specific descriptions. As with so many of the species described by early workers, host and geographical distribution have been relied on to distinguish the two species of *Otodistomum* and to these have been added the details not available to the original describers. Odhner and Dollfus (1937) have given most direct attention to the differentiation of the species and since they agree on host relationships of the species that have been reported from North America, the present writers accept their identification of the specimens from rays of the north Atlantic as *Otodistomum cestoides.*

In this recent critical review of the genus *Otodistomum,* Dollfus accepted Manter's analysis of the dimensions of the egg and Odhner's divergent evidences on thickness of the egg membranes. However, Dollfus did not accept Manter's identifications of the species but concluded that all North American materials represent varieties of the species *Otodistomum cestoides.* For some reason not known to the present writers, Dollfus throughout his paper uses the generic name *Otodistoma.* This is apparently a lapsus for in the original article Stafford (1904) clearly designated *Otodistomum* and this name has been used regularly in the literature since that date.

Relying on Manter's firm belief in egg size as discontinuous between two North American groups, Dollfus sought to add geographical limits to the distribution of varieties on this continent. In his key, he designated *O. cestoides cestoides* as occurring in *Raja* and *Chlamydoselachus* of the north Atlantic and north Pacific (with California included in the latter). He designated *O. cestoides pacificum* as found in *Raja* of the north Pacific and cited the State of Washington and Alaska. The egg measurements he obviously accepted directly from Manter's published observations. However, Dollfus (1937, footnote p. 431) did see material from *Raja binoculata* which had been collected at La Jolla, California (see Sleggs, 1927). Furthermore, he noticed that while eggs which he considered as typical in this California material ranged from 68 to 73 μ in length by 42 to 43 μ in breadth, there were other eggs which he classed as atypical which measured only 53 by 34 μ. Since he accepted Manter's evidence of discontinuity for the varieties which he designated as *O. cestoides cestoides* and *O. cestoides pacificum,* he concluded that both these varieties are to be found in the stomach of *Raja binoculata* which occupies the Pacific coast from Monterey to Sitka.

Linton (1901: 431) had recorded *O. veliporum* from the barn-door skate of the Woods Hole region but in his final summary of his studies

on trematodes from fishes (1940: 107) he corrected the determination to *O. cestoides,* adding several intermediate hosts and *Raja diaphanes* as apparently an accidental host. In his earlier observations, Linton cited 76 by 52 μ as egg measurements, while in his most recent work he gave 78 by 51 μ. Realizing that these measurements exceeded those recorded by Manter, Dollfus (still believing in discontinuous ranges in egg size) capitulated with the statement, "il est possible en effet que la longeur des oeufs dépasse un peu 72 μ."

An abundance of material of *Otodistomum* was collected from the barn-door skate (*Raja stabuliforis*) at the University of New Hampshire Marine Zoological Laboratory on Appledore Island of the Isles of Shoals near Portsmouth, New Hampshire, in the summer of 1939. For comparison with this material Dr. Harry G. Kimpel had collected a series of well preserved specimens from *Raja binoculata* at the Hopkins Marine Station of Stanford University, located at Pacific Grove, California, during the summer of 1937.

On preliminary examination of the material from California, it was noted that egg sizes were intermediate between the two distinct groups recorded by Manter. In this connection it should be noted that the Alaskan materials studied by Manter were from the same species of host (*Raja binoculata*) as the materials of the present study from Pacific Grove, California. The specimens from this same host from La Jolla, California, which Dollfus recognized as *Otodistomum cestoides cestoides,* are identical with the forms from *Raja stabuliforis* from Maine. Consequently our specimens from *Raja binoculata* from California were submitted to Dr. Manter for identification. In commenting on this material by letter, he mentioned the fact that though the material seemed to be identical with specimens which he had studied from Washington and Alaska, he had noticed that the eggs were smaller in our California material than in specimens at his disposal from farther north on the Pacific coast.

A careful study of a good series of worms in the collection of the senior author has revealed a complete obliteration of the supposed differences between the eggs of what Dollfus has called *O. cestoides cestoides* and *O. cestoides pacificum* as shown in Table 1. In securing information on the eggs, every effort was directed toward securing a fair sample. Ten well oriented eggs in the uterus of each mature worm were measured for length, diameter and thickness of the shell. Of the available mounts from *Raja binoculata* of Pacific Grove, California, 18 were mature, providing measurements for 180 individual eggs. Of the specimens from *Raja stabuliforis* of the Isles of Shoals, New Hampshire, 24 mature worms were used to secure data on 240 individual eggs.

A preliminary analysis of the measurements of entire worms used in

TABLE 1.—*Comparisons of American collections of* Otodistomum

	Body length in mm		Egg measurements in μ					
			Length		Diameter		Shell thickness	
	Range	Average	Range	Average	Range	Average	Range	Average
Host: *Raja stabuliforis* Manter, 1926 (Maine)	2.3–65			69.4		46.2		4.5
Linton, 1940 (Woods Hole)	7.5–54			ca 78.0		ca 51.0		3.0
Van Cleave and Vaughn (Isles of Shoals)	6.9–30.2	21.14	55–90	72.6	36–58	47.2	3–4	3.6
Host: *Raja binoculata* Manter, 1926 (Alaska)				85.5		57.8		4.0
Dollfus, 1937 (La Jolla)	ca 61		53–73		34–49		2–5	
Van Cleave and Vaughn (Pacific Grove)	23.9–69	43.98	60–94	77.2	40–70	52	3–5	3.67

this study seemed to indicate that while forms from the Pacific averaged longer than those from the Atlantic there was considerable overlapping in the ranges of the lengths. Further evidence of the instability of body length as a criterion for distinguishing varieties of *Otodistomum* is provided by the fact that Manter secured series of worms from *Raja stabuliforis* off the Maine coast, but a short distance from the area from which our specimens were taken from the same host species, and his worms were distinctly larger than the ones which we studied. It may be that the length of the growing period in an alternate host influences the size of the mature trematodes in the definitive host. Additional evidence of individual variation in size is provided by the size at which individuals reach sexual maturity. Manter states that "sexual maturity is attained between body lengths of 10 and 15 mm" but in our collection from the Atlantic coast one individual 6.9 mm long had the uterus filled with eggs while two individuals 6.1 and 7.6 respectively had no eggs. Size at which individuals of *Otodistomum* reach maturity shows great individual variability.

In an attempt to see if any correlation might exist between relative size of the mature worm and size of the eggs it contained, it was noticed that egg size was variable in all individuals regardless of the total length of the worm and that both large and small eggs appeared without distinct segregation in animals of the various lengths.

In an effort to find morphological features for distinguishing two species of *Otodistomum* in North American hosts, Manter reviewed the literature and made a careful search, but concluded that the two forms from the Atlantic and the Pacific could be separated only on the basis of

discontinuous ranges of egg sizes. Since the present series of observations on new materials from both coasts of North America show complete intergradation in egg size, this criterion no longer holds as the basis for separating two subspecies as proposed by Dollfus. Consequently, the present writers maintain that the American forms comprise a single highly variable species to which the name *Otodistomum cestoides* should be applied.

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THE SLENDER LICE OF AMERICAN PIGEONS AND DOVES WITH DESCRIPTIONS OF TWO NEW SPECIES

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The American Ornithological Union Checklist gives 21 species and subspecies of pigeons and doves. Of these, only six are found in large numbers over any considerable areas north of Mexico. The writer had hoped to secure lice from at least these six before studying the group critically. However the past fifteen years have brought in lice from only five different kinds of pigeons and doves. It is hoped that the present report may help to focus attention on the parasites of these birds so that lice from the other species and subspecies will be collected.

The slender lice of pigeons and doves at hand includes *Esthiopterum columbae* (Linn.) from the domestic pigeon and *Esthiopterum baculoides* (Paine) from the western mourning dove. Comparisons of these with lice from the eastern mourning dove, eastern ground dove and the band-tailed pigeon show that we must add two new species to those previously recognized.

Ewing erected the genus *Columbicola* for the slender lice of doves and pigeons in 1929 almost solely on the basis of two pairs of spines on the dorsal surface of the clypeus of *Esthiopterum columbae*. He describes an anterior and a posterior pair. These spines are present on the four species to be discussed. However, Malcomson (1937) in describing *Columbicola extincta* from the passenger pigeon states that the recurved setae (posterior spines) are not present. Until more lice from pigeons and doves can be critically studied to establish a more complete characterization of the group, the writer is considering *Columbicola* as a subgenus.

Esthiopterum (*Columbicola*) *passerinae* n. sp.
(Figs. 1–4)

Female, Fig. 1. Body form and chaetotaxy as shown by Fig. 1, the outline of which is a tracing of a microprojection of the allotype. Head length of this specimen is .528 mm; head width across temples .251 mm. From these measurements other dimensions may be computed from the Fig.

Male, Figs. 2, 3 and 4. Resembles the female in body form and chaetotaxy. Is slightly smaller. Third segment of antenna with thumb-like projection. Terminal segments of abdomen differ from female as shown by comparisons of Figs. 1 and 3. Following head measurements (in mm) are indicative of size and variation in the specimens available.

Head length	.489	.475	.482	.489	.475	.489	.475
Head width	.251	.238	.238	.251	.238	.238	.224

Male genitalia, Fig. 4, consists of a basal plate to which the parameres appear to be immovably joined. Endomeres are distinct, separate and short. Preputal sac

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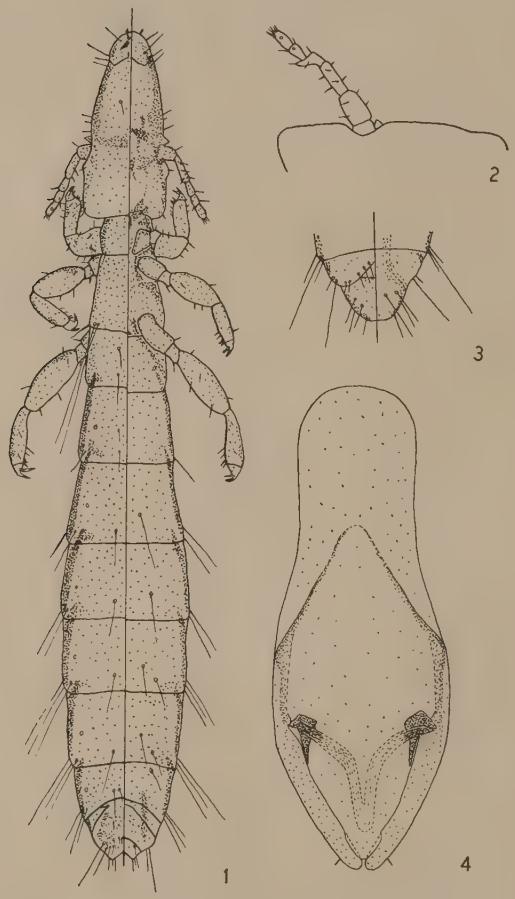


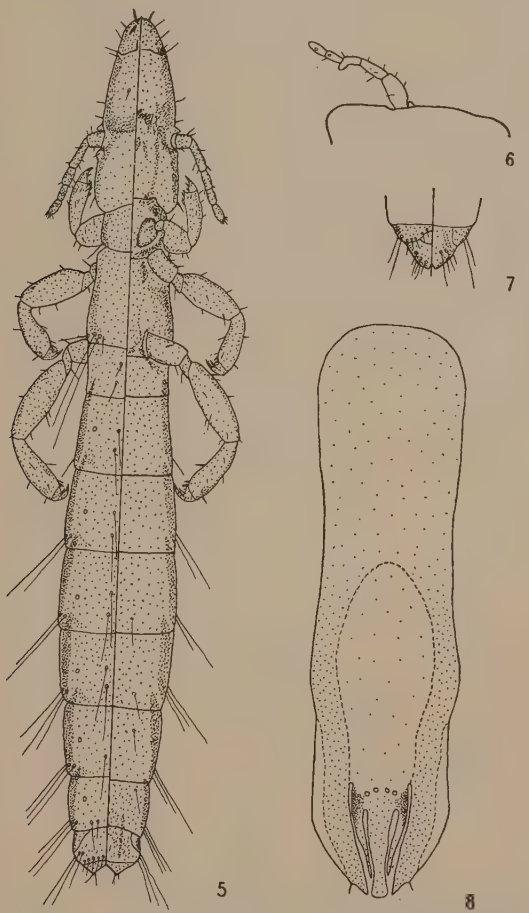
FIGS. 1–4. *Esthiopterum* (*Columbicola*) *passerinae* n. sp.
FIG. 1. Female; FIG. 2. Outline of head and antenna of male; FIG. 3. Posterior end of abdomen of male; FIG. 4. Ventral view of male genitalia.

or vesicula penis with a characteristic V-shaped thickening, the arms of which extend anteriorly to the endomeres and appear to articulate with them.

Host: Eastern ground dove, *Columbagallina passerina passerina* (Linn.): 6 males and 1 female collected by H. S. Peters at Auburn, Ala., April 4, 1936; 3 males collected at Slocumb, Ala., by A. G. Watkins, Jan. 4, 1937.

Types: The holotype male and the allotype are deposited in the Cornell University Collection. Paratypes are deposited in the following entomological collections: U. S. Nat. Mus., Washington, D. C.; Canadian National Collections, Ottawa, Canada; British Museum of Natural History, London, England; Stanford University, Calif.; Univ. of Minnesota, St. Paul, Minn.; Tulane University, New Orleans, La.

This species is characterized by its small size and male genitalia. The posterior clypeal spines are thickest just above the base whereas in the other species to be mentioned with the exception of *E. macrourae* they taper evenly from the base. The posterior clypeal spines are markedly thicker than any part of the anterior clypeal spines and longer. This is in contrast to *E. baculoides* (Paine) in which the posterior clypeal spines are less thick than even the basal part of the anterior clypeal spines and both pairs of spines are very slender and hair-like and about equal in length.



FIGS. 5–8. *Esthiopterum* (*Columbicola*) *macrourae* n. sp.
FIG. 5. Female; FIG. 6. Outline of head and antenna of male; FIG. 7. Posterior end of abdomen of male; FIG. 8. Ventral view of male genitalia.

Esthiopterum (*Columbicola*) *macrourae* n. sp.
(Figs. 5–8)

Female, Fig. 5. Body form and chaetotaxy as shown by Fig. 5, the outline of which is a tracing of a microprojection of the allotype. Head length of this specimen is .620 mm; head width across temples is .264 mm. From these measurements other dimensions may be computed from Fig. 5. Following head measurements (in mm) are indicative of size and variability:

Head length	.620	.620	.620	.620	.634	.607	.620	.607
Head width	.277	.290	.277	.264	.277	.264	.264	.277

Male, Figs. 6, 7 and 8. Resembles the female in body form and chaetotaxy. Is somewhat smaller. Third segment of antenna with thumb-like projection. Terminal segments of abdomen differ from female as shown by comparison of Figs. 7 and 5. Following head measurements (in mm) are indicative of size and variation:

Head length	.581	.581	.594	.554	.568	.581	.555	.554
Head width	.251	.264	.264	.238	.251	.264	.251	.264

Male genitalia, Fig. 8, consists of a basal plate to which the parameres are apparently fused. They have almost transparent lateral borders. Endomeres are elongated with thickened basal regions, extending medially and with mesal borders difficult to delineate.

Host: Eastern mourning dove, *Zenaidura macroura carolinensis* (Linn.): 4 males, 21 females and several young collected by T. F. Hall, Jr. Dec. 2, 1934; 8 males collected by Ernest Beck Dec. 2, 1934; 5 males and 8 females collected by Ernest Beck Dec. 21, 1934. All were collected near New Orleans, La.

Types: The holotype male and the allotype are deposited in the Cornell University Collection. Paratypes are deposited in the following entomological collections: U. S. Nat. Mus., Washington, D. C.; Canadian National Collections, Ottawa,

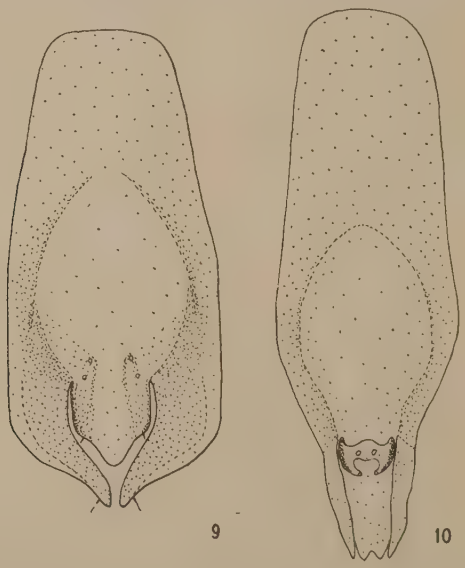


FIG. 9. Ventral view of male genitalia of *Esthiopterum* (*Columbicola*) *columbae* (Linn.).

FIG. 10. Ventral view of male genitalia of *Esthiopterum* (*Columbicola*) *baculoides* (Paine).

Canada; British Museum of Natural History, London, England; Stanford University, California; Univ. of Minnesota, St. Paul, Minn.; Herbert Osborn's Collection at Ohio State University, Columbus, Ohio; Tulane University, New Orleans, La.

This species is characterized by its head being longer than that of any of the other species mentioned, its relatively narrow temples, and the male genitalia. The male genitalia of *E. columbae,* Fig. 9, is given for comparison. The clypeal spines resemble *E. passerinae* but with a less noticeable enlargement near the base of each posterior spine. Anterior and posterior spines about equal in length.

The slender louse of the eastern mourning dove has been reported by previous workers (Peters, 1933; Geist, 1931) as *Esthiopterum columbae* (Linn.) or *Columbicola columbae* (Linn.). Emerson (1940) reports *Columbicola columbae* from a mourning dove without mentioning the variety of mourning dove.

It is expected that a critical examination of the specimens on which these reports were made would show them to be *E. macrourae,* except possibly the Oklahoma record. The eastern and western varieties of mourning dove are both found in Oklahoma.

DISCUSSION

A peculiar host specificity is exemplified by these lice on pigeons and doves. *E. columbae* seems to be restricted to the domestic pigeon. The report of *Lipeurus baculus* Nitzsch, a synonym of *E. columbae* (Linn.) on *Columbagallina passerina socorrocnsis* Kellogg and Mann, 1912, is probably an erroneous identification. It had been expected that the slender louse of the eastern and western mourning doves would be identical. Paine (1910) described *E. baculoides* from the western mourning dove. In this description he mentioned the absence of a thumb-like process on the third antennal segment of the male. The absence of this process mentioned in the description was questioned until the examination of a co-type loaned by the Stanford University Museum through the courtesy of Professor G. F. Ferris, showed the actual absence of this thumb-like appendage. The absence of this appendage was further checked by an examination of over 35 males collected from the western mourning dove at Pasadena, California, Aug. 21, 1937, by S. F. Wood. Paine's description checks in all details. Paine did not describe or figure in detail the male genitalia of *E. baculoides,* so, in order to complete the evidence for the separation of these two species, the male genitalia of Paine's species is illustrated in Fig. 10. The host relationships are further complicated by the fact that ten male and eighteen female lice, collected at Ojo de agua, Galeano, N. L. Mexico, Aug. 15, 1938, by H. Hoogstraal from *Columba fasciata fasciata* are indistinguishable from the new *Esthiopterum macrourae* from the eastern mourning dove except for the clypeal spines which are like those of *E. columbae.*

A comparative study of the male genitalia of the four species mentioned above is particularly interesting. The parameres of all are specialized in that they are immovably joined to the basal plate. The position of other parts points definitely to the place of fusion, and *E. baculoides* shows a thin line only, separating the parameres from the basal plate. This thin line indicates the place of fusion rather than a functional joint. The endomeres are more variable, showing as two separate and distinct structures in *E. passerinae* from the ground dove, and as separate, poorly delineated structures fused to the sides of the preputal sac or vesicula penis in *E. columbae.* In *E. macrourae* from the eastern mourning dove and from the banded pigeon, they are elongate, showing a mesal development. In *E. baculoides* they have grown together medially and form a distinctive endomeral plate.

Columbicola extincta was described by Malcomson (1937) from the passenger pigeon but the drawing of the male genitalia is not sufficiently clear to include it in the above comparisons.

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OBSERVATIONS ON THE VIABILITY OF EGGS OF LUNGWORMS OF SWINE*

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Little information is available concerning the survival period of eggs of swine lungworms on and in soil and the effects on these eggs of various environmental factors. An investigation was undertaken, therefore, to ascertain (1) the survival time of lungworm eggs in feces located on or beneath the surface of soil outdoors; (2) the effect on the survival period of the eggs of vegetation growing on the infested soil; and (3) the effect on the eggs of high and low temperatures and drying. It was considered that information of this nature could be used to improve current recommendations for the control of lungworms in swine.

EXPERIMENTAL PROCEDURE

In the tests herein described eggs of two species of lungworms, *Metastrongylus elongatus* and *Choerostrongylus pudendotectus*, contained in feces of naturally infected pigs were used. The measure of the viability of the eggs was the ability of the contained larvae to infect susceptible earthworms (*Helodrilus* species). Tests of the viability of eggs were carried out as follows:

Feces containing the eggs were first thoroughly mixed with moist, helminthologically-sterile soil in the proportion of approximately 14 grams of feces to 100 grams of soil. The mixture of soil and feces was then placed in finger bowls and six to eight earthworms were added to each container. The soil-feces mixture was covered with moist absorbent paper and the dishes were loosely covered to prevent excessive evaporation of moisture; the cultures were maintained at a temperature of 20° to 25° C for periods of 21 to 30 days. The earthworms from the cultures were then dissected, and the number of lungworm larvae present in the hearts and anterior portion of the digestive tract of each annelid was counted. The localization of the larvae in the latter region was described by Schwartz and Porter (1938). In cases where the larvae were massed in the hearts, the number was estimated as accurately as possible.

In the tests of the longevity of lungworm eggs on and in soil under outdoor conditions, 2,000 grams of feces, containing approximately 1,000 eggs per gram, were placed in each of eight unshaded plots prepared as follows:

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* This investigation was carried out from June, 1938, to December, 1939, at the U. S. Department of Agriculture Beltsville Research Center, Beltsville, Maryland.

Plot 1—Feces on top of soil kept free of vegetation
Plot 2—Feces on top of soil planted to barley
Plot 3—Feces 4 inches beneath surface kept free of vegetation
Plot 4—Feces 4 inches beneath surface planted to barley
Plot 5—Feces 6 inches beneath surface kept free of vegetation
Plot 6—Feces 6 inches beneath surface planted to barley
Plot 7—Feces 12 inches beneath surface kept free of vegetation
Plot 8—Feces 12 inches beneath surface planted to barley

When the vegetation on plots 2, 4, 6 and 8 died, these plots were reseeded. At intervals indicated in table 1 enough fecal material to fill

TABLE 1.—*Time lungworm eggs in feces on and in soil survived as determined by earthworm feeding tests on exposed eggs*

Plot number	Location of eggs	Date sampled	Duration of exposure	Earthworms examined	
				Number	Larvae recovered*
			Days		*Number*
Eggs on and in bare (unseeded) soil					
1	On surface	August 10, 1938	32	8	Less than 1
1	do	August 31, 1938	43	5	Less than 1
3	Buried 4 inches	do	43	1	21
5	Buried 6 inches	do	43	5	25
7	Buried 12 inches	do	43	3	182
1	On surface	February 2, 1939	198	4	0
3	Buried 4 inches	do	198	3	19
5	Buried 6 inches	do	198	3	26
7	Buried 12 inches	do	198	3	114
1	On surface	May 5, 1939	290	3	Less than 1
3	Buried 4 inches	do	290	3	11
5	Buried 6 inches	do	290	3	26
7	Buried 12 inches	do	290	3	55
1	On surface	November 9, 1939	381	3	0
3	Buried 4 inches	do	381	3	Less than 1
5	Buried 6 inches	do	381	4	1
7	Buried 12 inches	do	381	3	2
Eggs on and in grassy (seeded) soil					
2	On surface	August 10, 1938	32	4	1
2	do	August 31, 1938	43	7	0
4	Buried 4 inches	do	43	3	133
6	Buried 6 inches	do	43	5	105
8	Buried 12 inches	do	43	3	32
2	On surface	February 2, 1939	198	3	0
4	Buried 4 inches	do	198	3	38
6	Buried 6 inches	do	198	3	82
8	Buried 12 inches	do	198	3	105
2	On surface	May 5, 1939	290	3	1
4	Buried 4 inches	do	290	3	91
6	Buried 6 inches	do	290	3	114
8	Buried 12 inches	do	290	3	160
2	On surface	November 9, 1939	381	3	0
4	Buried 4 inches	do	381	4	7
6	Buried 6 inches	do	381	4	3
8	Buried 12 inches	do	381	4	0

* Average per earthworm.

without packing a 50 cc bottle was collected from each plot and the viability of the eggs ascertained by earthworm feeding tests. The sampling of the plots was terminated after 381 days as the fecal material in the plots had been largely exhausted by the sampling.

Tests involving the effect of low temperature on the eggs were con-

ducted with 14-gram samples of feces in tightly closed sputum jars subjected continuously to temperatures from −8° to −20° C or lower for periods from 3 to 108 days. At intervals (see Table 2) samples were

TABLE 2.—*Effect of continuous freezing at temperatures of −8° to −20° C on viability of lungworm eggs as determined by earthworm feeding tests*

Sample number	Period of exposure	Temperature of sample at removal	Earthworms examined	
			Number	Larvae recovered*
	Days	*°C*		*Number*
1	3	−11	3	230
2	7	−8	4	204
3	10	−10	3	219
4	14	−10	2	223
5	21	−12	3	279
6	24	−14	4	277
7	27	−12	3	188
8	38	−10	6	244
9	42	−14	4	323
10	46	−8	3	343
11	49	−8	3	142
12	63	−20	8	91
13	87	−10	5	99
14	108	−14	3	8
Control	108	2° C entire period	5	319

*Average per earthworm.

removed, allowed to thaw at room temperature, and the viability of the eggs tested. A control sample maintained at a temperature of approximately 2° C was tested for viable eggs at the same time as the last test sample.

In the tests involving the effect of desiccation on eggs, 5 grams of feces were evenly spread on each of several 3-inch square glass plates, and the feces partially dried in a strong current of air; the plates were then kept over calcium chloride in a partial vacuum for an additional period of approximately 6 hours to insure complete drying of the fecal material. Certain of these dried preparations were then subjected for varying periods to a continuous temperature of 17° to 22° C whereas others were subjected to a temperature of 37° C and still others to a temperature of 1° to 2° C. Control cultures were not subjected to desiccation.

Tests of the effect of high temperature on the eggs were carried out as follows:

Approximately 14 grams of moist feces containing eggs were tightly packed in each of a series of sputum jars that were tightly stoppered with corks each containing a thermometer for recording the temperature of the feces, and a capillary tube to permit escape of gases from the fecal material. The test jars were then immersed in a water bath held at the desired temperature. In some cases the jars were removed as soon as the temperature of the feces became equal to that of the water; temperatures of 40°, 50°, 55°, 60°, 65°, and 70° C were employed. In an-

other test, the jars were allowed to remain in the water bath for 10 minutes after the temperature of the feces had become equal to that of the water; temperatures of 40°, 50°, 55° to 60°, and 65° to 70° C were employed. In all cases when the jars were removed from the water bath they were immediately immersed in ice water until the temperature of the feces was approximately 30° C; the viability of the eggs was then tested by earthworm feeding. Control cultures were kept at a temperature of 25° to 30° C and were not subjected to higher temperatures.

EXPERIMENTAL RESULTS

The major results of these tests are summarized in Tables 1 to 3. The following brief presentation of the data will serve to point out some of the more outstanding facts elicited, and present certain data not summarized in tables.

Length of Survival of Eggs on and in Soil of Bare and Grassy Plots

The data summarized in Table 1 show that although the viability of the majority of eggs in feces located on the surface of plots 1 and 2 was destroyed in 32 days or less, a small number retained their viability as long as 290 days. As can be seen from the data, there was no significant difference either in rate of death of eggs or in maximum length of survival of eggs between the seeded and unseeded plots. It may be concluded from this, therefore, that under the condition of the test the moderately heavy growth of vegetation present on plot 2 did not materially affect the time of survival of the eggs.

In contrast to this the rate of death of eggs kept buried at varying depths beneath the surface (plots 3 to 8, inclusive) was noticeably less rapid during the first 290 days of the test. At this time the average number of larvae recovered from earthworms fed eggs from the surface plots 1 and 2 was one or less, whereas average infections of 11 to 160 larvae occurred in earthworms fed eggs buried to varying depths in plots 3 to 8. Subsequent to the first 290 days of the test the buried eggs may have died rapidly as only slight infections resulted from earthworm feedings 381 days after the beginning of the test (Table 1). However, this may have been due in part to depletion of the fecal material in the plots as a result of the sampling procedure, since only relatively small amounts of the fecal material could be located at the time the last samples were taken.

As adjudged by the results of the earthworm feeding tests carried out at 43, 198, and 290 day intervals on eggs in feces that had been kept buried 4 and 6 inches deep in plots 3 to 6, inclusive, the rate of death of eggs in the seeded plots was noticeably less rapid than in the unseeded plots. For example, in the first three feeding tests the average numbers

of larvae recovered from earthworms fed eggs from unseeded plots numbers 3 and 5 varied from 11 to 26, whereas the average infections in earthworms fed eggs from seeded plots numbers 4 and 6 varied from 39 to 133 (Table 1). In the case of the seeded plots numbers 4 and 6 the grass roots had penetrated into the fecal material rendering it less compact, and perhaps at the same time kept the moisture content more favorable for the survival of the eggs than was the condition in the unseeded plots.

In the case of eggs in feces buried 12 inches in plots 7 and 8, a distance too great for the grass roots to penetrate, no consistent difference was noted between the average infections of earthworms fed eggs from these plots at intervals throughout the test (Table 1). It is interesting to note, however, that during the first 290 days of the test the rate of death of eggs buried 12 inches was apparently less rapid than that of eggs buried 4 and 6 inches as adjudged by results of earthworm feeding tests. That is, larger numbers of lungworm larvae were recovered in the earthworm feeding tests of the viability of eggs in plots 7 and 8, than in the case of plots 3 to 6 inclusive. However, as stated previously, in the final sampling of plots 7 and 8 (November 9, 1939), only small amounts of the buried fecal material could be located, which may account in part for the very small number of larvae recovered in these tests.

Effect of Continued Low Temperatures on Eggs

As shown by the results of earthworm feeding tests recorded in Table 2, some lungworm eggs in feces were able to survive continuous freezing at temperatures of −8° to −20° C or lower as long as 108 days. During the first 49 days of the test, when the temperatures varied from −8° to −14° C, there was apparently no appreciable effect on the eggs as shown by the fact that the number of larvae recovered from earthworms in feeding tests carried out did not materially decrease during that period. During the period from the 50th to the 63rd day of the test the temperature of the freezing unit employed varied from −20° to −27° C, and during the entire 62nd day remained at −40° C; this may have accounted for death of some of the eggs shown by the small numbers of larvae recovered from the test earthworms during this period and later.

That the reduction in numbers of larvae recovered over this test period was due to the natural effects of the low temperature is indicated by the fact that 109 larvae (average) were recovered per earthworm from a control culture of feces kept 108 days at 2° C.

Effect of Continuous Desiccation on Eggs

As can be seen from the data presented in Table 3, although a small proportion of lungworm eggs contained in feces dried on glass was able

TABLE 3.—*Effect of desiccation at 1° to 2° C and 37° to 39° C on the viability of lungworm eggs as determined by earthworm feeding tests*

Test number	Period exposed	Temperature	Earthworms examined	
			Number	Larvae recovered*
	Days	*°C*		*Number*
1	½	17 to 22	3	19
2	3	do	4	8
3	4	do	2	4
4	6	do	3	4
5	7	do	5	10
Control	None	do	5	319
6	10	37	4	3
7	10	17 to 22	3	20
8	10	1 to 2	3	61
Control	None	17 to 22	1	295
9	25	37 to 39	3	0
10	25	17 to 22	3	0
11	25	1 to 2	3	37
Control	None	17 to 22	2	727
12	31	37 to 39	3	0
13	31	17 to 22	3	0
14	31	1 to 2	3	14
Control	None	17 to 22	3	422
15	38	37 to 39	3	0
16	38	17 to 22	3	0
17	38	1 to 2	3	30
Control	None	17 to 22	3	422

* Average per earthworm.

to survive 38 days continuous desiccation at a temperature of 1° to 2° C, none was able to survive 25 days or longer at a temperature of 17° to 22° C or higher. Moreover, continued desiccation of only 7 days at a temperature of 17° to 22° C under the conditions of the test was apparently lethal to the majority of eggs as shown by the fact that an average of only 10 larvae was recovered from earthworms fed eggs dried under these conditions as compared to an average of 319 larvae acquired by earthworms from control cultures (Table 3). These observations explain in part failure of the majority of lungworm eggs on soil to survive more than 32 days in late summer tests herein reported (Table 1).

Effect of High Temperatures on Eggs

In a series of tests in which the temperature of small quantities of moist feces containing lungworm eggs was raised rapidly to 60° C and then quickly lowered to about 30° C, small numbers of eggs survived and were able to infect susceptible earthworms. However, in a later series of tests no eggs survived temperatures of 55° C or higher.

In order to determine the thermal death point of the eggs, a series of cultures was subjected to temperatures of 40°, 50°, 55° to 60°, and 65° to 70° for 10 minutes each. As determined by earthworm feeding tests, small numbers of eggs survived temperatures of 40° and 50° C but none survived 55° C or higher.

DISCUSSION

Data herein reported with regard to the marked resistance of lung-

worm eggs to continued low temperatures and their long survival in soil under favorable moisture conditions serve to explain in part the occurrence of lungworm-infected earthworms in soil of areas unused by hogs for as long as 4 years (Schwartz and Alicata, 1934; Spindler, 1938). The facts set forth in this paper have a bearing on the control of lungworm infections in pigs by management practices. Since as shown in the data lungworm eggs are most susceptible to desiccation and high temperatures, raising pigs on well-drained temporary pastures where lungworm eggs would be exposed to the inimical effects of dryness and the high temperatures engendered by the sun may be the most effective of the control measures against this parasite. In view of the long period of survival of lungworm eggs herein reported, plowing under of soil contaminated with lungworm eggs and growing a crop thereon might not be effective in hastening the destruction of the eggs but might on the contrary favor their survival. In light of the data presented in this paper, permitting an area to lie fallow for a period of at least a month during summer following removal of lungworm-infected animals should hasten destruction of lungworm eggs by desiccation and high temperatures. Subsequent plowing would tend to scatter the remaining viable eggs to such an extent in the soil that earthworm infections would be reduced to a minimum. Such measures might aid materially in controlling lungworm infections in pigs subsequently maintained on the areas in question.

SUMMARY

A series of tests designed to ascertain (1) the survival time of eggs of swine lungworms (*Metastrongylus elongatus* and *Choerostrongylus pudendotectus*) on and in soil, (2) the effects of low and high temperatures, and of drying on these eggs were carried out at Beltsville, Md.

The viability of eggs in feces on the surface of unshaded outdoor plots was destroyed in about 25 days. Some eggs in feces buried 6, 8, and 12 inches survived 381 days, but most of these eggs succumbed in about 290 days.

Under laboratory conditions the viability of eggs in moist feces was destroyed by short exposure to a temperature of 55° C. Eggs in moist feces survived 108 days at a temperature of –8° C to –20° C.

Eggs in dried feces were destroyed in 25 days at a temperature of 17° to 22° C. Eggs in dried feces at a temperature of 1° to 2° C were still viable after 38 days.

Information contained in this paper suggests that permitting soil contaminated with swine lungworm eggs to lie fallow about a month before plowing should be useful in controlling these parasites.

Bibliography

Schwartz, Benjamin and Alicata, Joseph E. 1934 Life history of lungworms parasitic in swine. U. S. Dept. of Agric. Tech. Bull. No. 456. 41 pp.

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REVIEWS

AN INTRODUCTION TO NEMATOLOGY. By B. G. Chitwood and M. B. Chitwood, with the collaboration of A. C. Walton, Reed O. Christenson, Leon Jacobs and F. G. Wallace. Section I, Part III, and Section II, Part I: pp. 125–240, Figs. 112–164. Published by the authors, Babylon, N. Y. 1940. $4.50.

This publication is the concluding portion (Part III) of Section I and the first part of Section II of a comprehensive treatise on nematology. As was to have been expected, the authors have produced an excellent companion piece for the preceding portions, the first of which appeared in 1937, the second in 1938. Section I, Part III, contains five chapters (IX–XIII). The first three are concerned with the excretory system, the reproductive system, and the nervous system. In them, the fundamental patterns and variations which characterize these systems in various nema groups are skillfully analyzed. Collation of the extensive literature on these subjects, to which the authors have contributed significantly themselves, has resulted in a product for which the authors deserve much praise.

Chapter XII, prepared by R. O. Christenson with the collaboration of Leon Jacobs and F. G. Wallace, is entitled "Nemic Ova" and deals primarily with the morphological variations encountered in the eggs of a wide variety of nemas. Attention is also devoted to the chemical character of the egg membranes. The chapter contains two excellent full page plates of drawings illustrative of the various types of eggs from representative nemas. No student of parasitology should deny himself the examination of these figures, or for that matter, possession of the "Introduction."

To those with zoological backgrounds, the last chapter (XIII) of Section I will prove interesting. Dealing as it does with the controversial subject of "Nemic Relationships," one would expect sufficient latitude for considerable disagreement. The author, B. G. C., has been conservative and competent in dealing with zoological groups outside his special field. A careful reading of the chapter impresses one that he has also recognized the limitations inherent in the subject and has striven to be objective concerning the tangible characters which must be evaluated in reaching any conclusions regarding relationships. Differences with the author's conclusions which may ensue, will arise primarily from a lack of agreement on the fundamental characters to be considered and the assessment of their value for the end in view. The historical aspect of the subject has been handled well and is interesting reading. The author's tabulation and evaluation of characters in various groups is ingenious and deserves critical study.

The concluding three chapters are in Section II, Part I. The first, by A. C. Walton, is a concise résumé of extant knowledge on gametogenesis, meiosis and fertilization. A table of chromosome numbers and other pertinent information covering 50 different nematodes is included. Chapter II deals with "Nemic Embryology" and covers the principal aspects of the determinate cleavage and constancy of cell numbers which characterizes the development of these animals. The final chapter is on postembryonic development. Numerous variations in the development of nematodes are recorded and several hiatuses in existing knowledge on the subject indicated.

In keeping with the precedent established for the previously issued parts of this treatise, the present part is profusely illustrated and each chapter concludes with an extensive bibliography. The compilation and integration of the information on nematodes which is represented in this part, as well as in the preceding parts, was a monumental undertaking. The Chitwoods are to be congratulated on the success they have achieved. It is not inappropriate to refer to the data recorded on the last page. Clearly, the authors merit more financial support for this personal venture than they seem to be getting from zoologists, parasitologists and nematologists generally.

It is necessary to call attention to the fact that the printing is inferior in quality in comparison with that of the previous parts. Whether the economy achieved was worth the price is debatable. It is likewise unpleasant to note that the proof was not corrected with the care which the reviewer believes the publication merited: a list of 70 errata, typographical and otherwise, observed by the reviewer in 115 pages seems remarkably long. Perhaps one should not notice mediocrity on this point when the substance is so fine.—GEORGE L. GRAHAM.

CLINICAL PARASITOLOGY. By Charles Franklin Craig and Ernest Carroll Faust. 772 pages, 244 illustrations. Lea and Febiger, Philadelphia. 1940. 2nd edition. $8.50.

The necessity for bringing out a second edition of this work within three years after the first (reviewed, 1938, J. Parasitol. **24**: 94) attests the cordial reception that it has received. In preparing the new edition the authors have taken full advantage of the opportunity to revise the original text and to include recent additions to knowledge in the subject. The present volume contains 39 more pages and several new illustrations. The most notable addition is a new chapter on leeches of medical importance. The technical appendix has been enlarged to include some of the more recent diagnostic procedures such as the zinc sulfate flotation technic and the NIH anal swab technic of examining for pinworms. The many recent contributions to knowledge of tick-borne diseases and the epidemiology of yellow fever and plague are adequately covered. Since the text is so up to date in other respects, it is to be regretted, however, that more adequate discussion is not given to the latest work on immunity in experimental helminth infections.

The new edition maintains the high standard of typography and excellence of printing established by the first. Few errors were detected. On page 273, however, the amount of blood withdrawn per day by a hookworm in the intestine is erroneously given as 0.1 cu mm, which would be a negligible amount.

An extensive bibliography, together with a complete author index, greatly enhances the value of the book for reference. The work is to be highly recommended to graduate students in parasitology and also to medical students and practitioners who wish to have a complete, authoritative and up-to-date text on the subject.—O. R. MCCOY.

A GUIDE TO HUMAN PARASITOLOGY FOR MEDICAL PRACTITIONERS. By D. B. Blacklock and T. Southwell. 259 pages, 122 illustrations and 2 colored plates. Williams and Wilkins, Baltimore. 1940. 4th edition. $4.00.

The present edition of this work, which is intended primarily as a manual for beginners interested in human parasitology, is essentially unchanged from the last edition issued in 1938 (reviewed, 1939, J. Parasitol. **25**: 515). The only changes discovered are a slight revision of the table of the life cycle of *Strongyloides* (page 171), the addition of several footnotes and the correction of misprints. Because of the simplified presentation, the book will continue to be of value to the medical practitioner or public health worker with a superficial interest in the subject. The numerous epidemiological tables and charts of life histories are particularly valuable in this respect.

With the exception of brief mention of myiasis in a chapter of miscellany, medical entomology is not included in the subject matter. A short chapter is devoted, however, to the spirochaetes, although it is recognized that this group is more closely related to the bacteria than to the protozoa. In view of the space devoted to some of the rarer helminth parasites, it would seem that the intestinal flagellate group is deserving of more extensive consideration. For instance, *Trichomonas vaginalis* is not mentioned anywhere in the text, in spite of the fact that this parasite is recognized to occur commonly in all parts of the world and the question of its pathogenicity is widely debated in gynecological literature. The reviewer would also suggest that the subject matter in the latter chapters of the book could be more logically arranged. Since the terminology is on the whole up

to date, it is to be regretted that *"Taenia granulosa"* is used instead of *Echinococcus granulosus,* the name approved by the International Commission on Zoological Nomenclature.

This work is to be recommended particularly to those who desire a concise aid for the diagnosis of human parasites. Also, it may well be used as a text-book by medical students who receive only brief training in the subject of parasitology.—O. R. McCoy.

1940 Year Book of Public Health. Edited by J. C. Geiger. 560 pages. The Year Book Publishers, Inc., 304 South Dearborn Street, Chicago. $3.00, postpaid.

This volume by Dr. Geiger (Director of Public Health, San Francisco) attempts to survey the advances in the field of public health. The following subjects are considered:

1. Communicable Diseases and Epidemiology: 1a, General; 1b, Tuberculosis; 1c, Poliomyelitis; 1d, Malaria; 1e, Venereal Diseases. 2. Food and Milk. 3. Nutrition. 4. Housing. 5. Statistical. 6. Laboratory. 7. Industrial Hygiene. 8. Administration: 8a, Medical Care; 8b, Maternal Care. 9. Health Education. 10. Child Hygiene; 10a, General; 10b, Dental Hygiene; 10c, Mental Hygiene; 10d, Nursing.

The book consists of abstracts of papers published during 1939 and 1940. Following a number of the abstracts are personal evaluations by Dr. Geiger. The articles abstracted are gathered rather widely from the literature. Many of them appeared in journals and foundation reports which the average worker in public health might not see. The book is thoroughly indexed by subject and author. This book should serve a very useful purpose and enable busy health workers to keep abreast of an ever increasing literature.—H. W. Brown.

AMERICAN SOCIETY OF PARASITOLOGISTS

Sixteenth Annual Meeting, Philadelphia, Pa.

December 30 and 31, 1940, and January 1, 1941

Minutes of Sixteenth Annual Business Meeting

The sixteenth annual business meeting of the Society was held at the Hotel Philadelphian on December 31, 1940, following the annual Parasitologists' Luncheon which was attended by 158 members and guests. The meeting was called to order at 2:00 PM by President David H. Wenrich who expressed his gratification for the large attendance, including seven former Presidents of the Society, Henry B. Ward, W. W. Cort, William A. Riley, W. H. Taliaferro, George R. LaRue, F. C. Bishopp and Horace W. Stunkard.

I. Reports of Officers

1. The report of the Secretary was presented. As of December 5th, there were 479 members on the roll, including 48 in arrears. Sixty new members were elected during 1940. The deaths of the following members occurred during the past year:

J. Lee Kirby-Smith, practising physician, January, 1940, in Jacksonville, Florida.

Harvey P. Barret, retired physician, July 30, 1940, in Charlotte, N. C.

Ralph K. Collins, Field Director in the International Health Division of the Rockefeller Foundation, October 1, 1940, in New York City.

The secretary reported the following actions of the Council at its meeting held on December 29, 1940:

(1) Amendment of the By-Laws in regard to the allotment of time for papers on the program to read, "If the program is crowded, the maximal allotment of time may be reduced to 10 minutes."

(2) Passage of a resolution to go on record as not approving the description of new genera and new species in abstracts for the program.

(3) Passage of a new By-Law to provide for the management of the Endowment Fund as follows:

> "Council shall select a Custodian of the Endowment Fund and two associates to whom it may delegate responsibility for management of the Fund. The Custodian shall make an annual accounting to Council and such other reports as Council may request. The approval of two of the three custodians shall be necessary for the purchase, sale or exchange of securities. One of the three custodians shall be the Treasurer of the Society and his signature shall be required on all vouchers of expenditure from the Fund."

(4) Proposal to the Society that the Constitution be amended to provide that the Chairman of the Editorial Committee shall be ex officio a member of the Council.

Upon motion the report was approved and placed on file.

2. The report of the Treasurer was presented by Dr. Gilbert F. Otto. A favorable operating margin for the year of $141.80 wiped off the book deficit of $106.42 remaining from the past 5 years and also the $32.75 current deficit on the 25-volume Index, leaving an unexpended balance of $2.62. The Treasurer pointed out that his estimate of 1941 income was conservative, and perhaps pessimistic, being based on the assumption that the Journal would lose 55 more non-member subscribers on account of war conditions abroad. During 1940 there was a decrease of 27 in non-member subscriptions from foreign countries. According to this estimate the Society would incur a deficit of approximately $465 in publishing a 600-page Journal during the coming year.

Upon motion the report, certified as correct by the Auditing Committee, was accepted with a vote of thanks to Dr. Otto for his services as Treasurer during the past four years.

II. Reports of Committees

1. The report of the status of the Secretarial Fund was presented by Dr. Norman R. Stoll, Custodian. Upon motion the report, certified as correct by the Auditing Committee, was accepted and placed on file.

2. The report of the Editorial Committee was presented by Dr. Norman R. Stoll, Chairman. "The Journal of Parasitology itself (Volume 26 in 6 numbers of 539 pages, and the December Supplement of 48 pages), regularly issued on schedule, constitutes the main report of the Editorial Committee for 1940. In addition a 25-Year Index to the Journal is well advanced toward final publication. The Author Index of 3,397 items is in page proof, the general Subject Index is in part in type, and the Host Index is ready for checking of copy for accuracy. The 25–Year Index will constitute, at completion, a book of about 200 pages, at a pre-publication price to members of the Society of $1.00, and a uniform post-publication price of $2.00. Its pre-publication sale to date promises its success financially."

Upon motion the report was accepted with a vote of thanks to the Editorial Committee.

3. The report of the Biological Abstracts Committee was presented by Dr. George L. Graham, Chairman. It was pointed out that the loss of foreign subscribers to Biological Abstracts on account of the spreading war abroad makes it imperative, now more than ever before, that American biologists support Biological Abstracts if it is to maintain its standard of publication. Upon motion the report was accepted.

4. A condensed report of the Committee on Nomenclature was given by Dr. Paul D. Harwood, Chairman. It was the opinion of the Committee that under the International Rules of Zoological Nomenclature *Trichuris* rather than *Trichocephalus* is the valid generic name, and that *Dioctophyma renale* is the valid name for the giant kidney worm. (The complete report of the committee is appended.)

Upon motion the report was accepted.

III. Reports of Representatives of the Society

1. Representatives on the Council of the American Association for the Advancement of Science. Since the proceedings of the Council will be published in *Science*, Dr. LaRue offered no report at this time.

2. A brief report of the representatives on the Council of the Union of American Biological Societies was presented by Dr. Earl C. O'Roke. The financial straits of Biological Abstracts are not as serious as was feared several months ago and it is expected that regular publication can be maintained without any curtailment during the coming year. Forty-three lapsed foreign subscriptions are being continued through underwriting by philanthropic agencies in this country.

Upon motion the report was accepted.

IV. New Business

The following two amendments to the Constitution proposed at the fifteenth annual meeting in Columbus were adopted by unanimous vote:

> Journal of Parasitology. This Journal, the property of the Society, is its official organ. Responsibility for its conduct shall rest with the Council which shall select the editorial staff and set the price of subscription.
>
> Endowment Fund. Provision is made for the establishment of a permanent Endowment Fund, the principal of which may be expended only by a three-fourths vote of all members of the Council and approval by a three-fourths vote of the members of the Society present at a regular

meeting. The Council shall be entrusted with the maintenance of the fund, and the use of the income therefrom.

Upon a motion in accordance with the recommendation of the Council, it was voted that the selection of the 1941 meeting place be held in abeyance and that the Council be entrusted to decide the meeting place.

The Secretary presented the Council nominations for officers of the Society for 1941, as follows: President, James E. Ackert; Vice-president, Justin Andrews; Treasurer, for two years, Lloyd E. Rozeboom; Members of the Council, for four years (to succeed Justin Andrews and Norman R. Stoll), Donald L. Augustine and Norman R. Stoll; Members of the Editorial Board, for four years (to succeed H. E. Ewing, J. F. Kessel and H. J. VanCleave), E. Harold Hinman, Richard P. Hall and Justus F. Mueller; Representatives on the Council of the American Association for the Advancement of Science, George R. LaRue and William A. Riley; Representatives on the Council of the Union of American Biological Societies, George L. Graham and Earl C. O'Roke. There were no further nominations and upon motion, duly seconded, the Secretary was instructed to cast one ballot for the nominations as presented.

A vote of thanks was extended to Dr. Robert M. Stabler, local representative of the Society in Philadelphia, for his services in making arrangements for the luncheon and the demonstration program.

There being no further business, it was voted to adjourn at 3:00 PM.

Respectfully submitted,

O. R. McCoy, *Secretary*

CHANGES IN MEMBERSHIP OF THE AMERICAN SOCIETY OF PARASITOLOGISTS SINCE PUBLICATION OF THE MEMBERSHIP ROSTER, DECEMBER SUPPLEMENT, 1939

New Members Elected

Josephina Acosta
Cyrus V. Anderson
John P. Barrett
José G. Basnuevo
Jonas L. Bassen
Enrique Beltran
Marjorie Biddle
Virginius E. Brown
Martha Bunting
Harold Burnstein
Arthur A. Case
S. L. Chang
Frederick Coulston
Helen Churchill
Joseph S. D'Antoni
Zacarias de Jesus
Elaine T. Delaume
William E. De Turk
S. Allen Edgar
Leslie L. Eisenbrandt
Kary C. Emerson
Albert M. Fallis
Marion M. Farr
Anna M. Fisher
Lyman P. Frick
Deane P. Furman
Tomas M. Gan
Chauncey G. Goodchild
Seymour Hadwen
Merle F. Hansen
Aaron B. Hardcastle
William B. Hopp
Herbert S. Hurlbut
Kathleen L. Hussey
Nobutaro Ishii
Harry A. Jankiewicz
Frances Jones
Kenneth C. Kates
Walter Kessler
Fred J. Kohlruss
Emil Kotcher
Robert E. Kunz
Raymond L. Laird
William K. Lawlor
Herman Lent
Alice Smith Leonard
Arthur Levin
Ralph D. Lowell
Francis W. Ludwig
Everett E. Lund
Walter S. Lundahl
José F. Maldonado
Rustum Maluf
Manuel Martinez-Baez
Joseph C. McCaffrey
Charles W. McNeil
Banner Bill Morgan
Donald V. Moore
Emma S. Moss
Ross F. Nigrelli
José Oliver-Gonzalez
Eddy A. Palmer
James P. Parker
Eduardo A. Pequeño
Trinidad P. Pesigan
Collins A. Pipkin
Karl R. Pomrenke
David Price
Robert J. Reiber
W. Malcolm Reid
Leslie W. Remley
Robert C. Rhodes

Kenneth I. Rhude
Anthony T. Rozycki
Robert L. Rutherford
John G. Salsbury
Aaron Seamster
Herman A. Shelanski
Victor Sprague
Glenwood M. Spurlock
Harry H. Stage
Dorothy E. Strahan
Vivian Sweibel
John H. Tetley
John E. Tobie
Charles M. Vaughn
Harold E. Wallace
Helen J. Werby
Evaline West
Francis M. White
Raymond W. Wilhelmi
Ruby A. Wortham
Herman Zaiman

Resignations

Veronica Armaghan
Alice T. Ashton
Charles C. Bass
John A. Cameron
Walter C. Earle
Charles S. Gibbs
George D. Jelen
Francis B. Johnson
E. Elizabeth Jones
Miriam Scott Lucas
Helen Stewart Lyford
Rafael Rodriguez-Molina
Lauren E. Rosenberg
Fred L. Soper
J. Paul Visscher

Deaths

Harvey P. Barret
Ralph K. Collins
John E. Guberlet
J. Lee Kirby-Smith
Charles W. Stiles*

SUPPLEMENT TO THE REPORT OF THE SIXTEENTH ANNUAL MEETING OF THE AMERICAN SOCIETY OF PARASITOLOGISTS

Report of the Committee on Nomenclature

Trichuris Roederer, 1761 vs. *Trichocephalus* Schrank, 1788

Since the name *Trichuris* Roederer, 1761, clearly antedates all other technical names proposed since 1758 for the genus of the whipworms, this name should be employed, providing the requirements laid down in the International Rules of Zoological Nomenclature are met by the original description. These requirements are few.

The name was published and accompanied by a description of the parasite (Art. 25a) as two brief quotations from the original demonstrate (Roederer, J. G. [in Secretary's abstract by Wagler.] Götting. Anz. gelehrt. Sachen (1761–62) 25 St. 1: 243): "Bey eben dieser Zusammenkunft las der Hr. Leibmed. und jetziger Prorector Röderer eine Abhandlung vor, welche eine gewisse bisher noch nicht beschriebene Art Würmer im menschlichen Körper betrift. Sie ist den dreyen bisher bekannten, dem runden Wurme, dem Bandwurme, dem Spulwurme, beyzufügen, und wird, ihrer Gestalt gemäss von Hrn. R. Trichuris (Haarschwanz) genannt;" and (p. 245): "Diese neue Art von Würmern der Eingeweide liesse sich also nach der Linnäischen Art so beschreiben: Corpus teres, longa proboscis filiformis, genitale curuarum, emineus, rectarum, apertura lateralis." Since Roederer (1761) stated he was describing the parasite "after the Linnaean manner" i.e., the binary manner (Stejneger, 1924. Smithsonian Misc. Coll. 77 (4): 1–21), it may be assumed that he "applied the principles of binary nomenclature" as required under Art. 25b (International Rules of Zoological Nomenclature).

Some authors have rejected the name *Trichuris* because it was not used in a binomial combination, but Article 2 of the Rules states: "The scientific designation of the animal is uninominal for subgenera and higher groups," and in Opinions 20, 24, and particularly 46 the International Commission on Zoological Nomenclature has consistently recognized uninominal generic names employed in a binary sense regardless of whether or not the name was used in a binominal combination. Therefore, the name in question should not be rejected because it is uninominal.

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* Life member.

At least one author has claimed that the name *Trichuris* Roederer, 1761 was used as a specific name. However, the evidence contained in the original description indicates that Roederer was proposing a generic name. *Trichuris* is a noun, not an adjective such as Linnaeus usually used for specific names, and furthermore, Roederer's description "nach der Linnäischen Art" is precisely in the style which Linnaeus (1758, p. 648. "Ascaris. *Corpus* teres, filiforme, continuum, utraque extremitate attenuatum.") employed when he wrote the diagnosis of the genus *Ascaris*, and it does not agree with the style employed for specific diagnosis. Authors contemporary with Roederer (Goeze: 1782, Versuch eine Naturgeschichte der Eingeweidewürmer thierischer Körper, Blankenburg) as well as other writers treated *Trichuris* as a generic name and renamed the genus, *Trichocephalos* (= *Trichocephalus*) hair-headed, because of the anatomy of the parasite. If some doubt whether or not Roederer intended to use the name *Trichuris* in a generic sense, in the abstract of his original paper, a later contribution by the same author should remove this doubt. (Roederer, J. G. and Wagler, C. G. 1783, Tractatus de morbo mucosa. Denuo recusus annexaque praefatione de *Trichuridibus* novo vermium genere, editus ab Henrico Augusto Wrisberg. Gottingae). The above title proves unquestionably that *Trichuris* was used as a generic name by the original author.

Accordingly the name *Trichuris* Roederer, 1761 appears to be available under the International Rules, and in our opinion it should be used as the correct name for the whipworms. *Trichocephalos* Goeze, 1782 and *Trichocephalus* of authors are synonyms.

COMMITTEE ON NOMENCLATURE,
PAUL D. HARWOOD, *Chairman*
B. G. CHITWOOD
ALLEN MCINTOSH

The status of *Dioctophyma, Dioctophyme,* and *Eustrongylus*

Collet-Meygret (1802, J. Phys. Chimie, Hist. Nat. et Arts, **55**: 458–464) proposed the name, *Dioctophyme,* for a worm from the kidney of a dog. He gave an extended description of the worm and an illustration of a dissection. When he first presented this paper before the "Societé philomatique de Paris" he stated that he felt sure it was a new genus, but he would leave the point to a study by specialists of this order of animals. In a section of this paper labelled "Remarque" (p. 463) the author states that the society appointed two members to verify his observations and determine whether it was essentially different from other known worms. The opinion arrived at is set forth in the original article as follows:

"Ils ont en conséquence jugé, comme moi, que cet individu devoit former un genre nouveau, très-voisin de celui des ascarides. J'établis donc ce nouveau genre, auquelje vais essayer de donner une dénomination, et d'assigner des caractères.

"Quant à la dénomination, comme elle doit être tirée des attributs qui, en même temps qu'ils offrent quelque chose de constant, frappent d'abord nos sens, j'ai préféré la faire dériver du nombre des tubercules; et comme il y en a huit à la tête et huit à la queue, sans égard pour leur disposition, j'ai adopté le mot *dioctophyme* (author's italics) composé de di, venant de *dis* (deux fois), *octo* (huit), *phyma* (tubercle), expression qui, je crois, remplit le but que je me propose.

"Voici quels sont les caractères du genre dioctophyme:

"*Corps alongé, cylindrique, articulé, à extrémités mousses, garnies chacune de huit tubercules; bouche terminale, anus également terminal; réunion des deux sexes* (1)."

It is obvious from the description appearing in the original article that the worm which Collet-Meygret discussed was the form which has been known variously as *Dioctophyme renale, Dioctophyma renale,* and *Eustrongylus visceralis.* Furthermore, it is obvious that Collet-Meygret intended to employ the term *"dioctophyme"* in a generic sense as he employs the phrase "du genre *dioctophyme"* in the quotation cited above. Therefore, it is the opinion of your committee that the conditions laid down under Article 25 (the law of priority) of the International Rules of Zoological

Nomenclature were fully met by Collet-Meygret, and the name *"dioctophyme"* should date from his paper. This opinion has no bearing on question of the emendation of the original spelling.

Some authors (Leiper, 1926) have rejected *"dioctophyme"* on the grounds that the original author was employing it as a vernacular term instead of a scientific name. Although the orthography suggests that Collet-Meygret intended to use *"dioctophyme"* in the vernacular, the statements which are quoted above, appearing in the original description indicate that the author was proposing a technical name in conformity with the principles of binary nomenclature. The error appearing in the original orthography may be corrected under the authority of Article 19 of the International Rules of Zoological Nomenclature. Acting in accordance with this authority, your committee recommends the adoption of the generic name *Dioctophyma* Collet-Meygret, 1802, as emended by Lamouroux in 1824. *Eustrongylus* Diesing, 1851, becomes a synonym under the law of priority.

Opinions 26, 27, 34, 41, 61, and 63 indicate that the policy of the commission has been to recognize emended spellings in those cases where the derivation of the word is clearly indicated, but as Stiles and Baker (1935, National Inst. Health, U. S. Pub. Health Serv., Bull. No. 163: 981) have stated, there exists a difference of opinion among zoologists "as to how far the principle of emendation should be applied." Consequently, to obtain uniform usage your committee recommends that the American Society of Parasitologists request the International Commission on Zoological Nomenclature to place *Dioctophyma* on the Official List of generic names.

Regarding the specific name of the kidney worm of carnivores, the following may be considered, namely: *Renales* Goeze, 1782; "Gigas," a group name employed by Goeze, 1782; *visceralis* Gmelin, 1790; and *renalis* Gmelin, 1790. The specific name *gigas* Rudolphi, 1802, which has been used by authors, is clearly antedated by the names listed above.

The passage by Goeze (1782, p. 39) involving the names in question is quoted below.

"I. Geschlecht (Genus)
der Rundwurm (Ascaris).

1. Der Riese: Gigas. Dieser begreift die grössern Arten unter sich.
   a) der Pferde: die grösste Art, die ich kenne.
   b) der Menschen: die eigentlich sogenannten Spulwürmer: Ascaris *Lumbric.* Linn.)
   c) der Schweine: schmächtiger und elastischer: mit einer, längs dem Rücken laufenden Orangegelben Streife.
   d) der Kälber: noch länger, und dünner, als die vorigen.
   e) Nierenrundwürmer, *Renales.*
   f) der Seehunde: *Phoca.*
2. Der Mittelrundwurm: *Teres*) von Mittelgrosse, wie Darmsayten. . . .
3. Der Madenrundwurm: Asc. *minutior.* . . ."

Later in the same article (p. 62) Goeze states, "Nach meinen Erfahrungen hab' ich drey Hauptklassen dieses Wurms kennen lernen: die grosse: die mittlere; und die kleine. Die erste nenne ich den Riesen, *Gigas;* die zwote den mittelrundwurm, *Teres;* die dritte den Madenrundwurm, *minutior.*" Because of the above statement we believe that the names *Gigas, Teres,* and *minutior* are group names which do not have nomenclatural status. In this respect they are similar to the group names, *Didelphys, Tridelphys, Tetradelphys,* and *Polydelphys* which modern authors use to subdivide the genus *Physaloptera.* (See Ortlepp, 1937, Onderstepoort J. Vet. Sc. and Animal Industry, 9: 71) and which possess no nomenclatural status. The case is also similar to the generic subdivisions employed by Linnaeus in the tenth edition of the Systema Naturae (pp. 425–433). Linnaeus divided the genus *Gryllus* into sections, namely, *"Mantis," "Acridia," "Bulla," "Acheta," "Tettigonia,"* and *"Locusta."* In Opinion 124, the International Commission on Zoological Nomenclature has ruled: "The various subdivisions of genera published by Linnaeus in 1758 are

not to be accepted as of this date (1758) as of subgeneric value under the International Rules." In view of these examples it seems justifiable to ignore Goeze's group names.

Although it may be argued that Goeze did not make the combination *Ascaris renalis*, the table, which is quoted above, indicates that his usage was both binary and binominal. Furthermore, "*Renales*" was printed in the same type as the specific name, "*Lumbric.* Linn." in Goeze's book, a circumstance which indicates that it was used as a technical name.

A comparison of Linnaeus (1758) with Goeze (1782) demonstrates that there is no essential difference between the two styles. The fact that Goeze was somewhat less consistent than Linnaeus is unfortunate but not important from the standpoint of nomenclature. Interpreting Goeze's style in view of the historical situation, we must conclude that it was binominal in the Linnean sense. Therefore, we consider that the specific name "*Renales*," Goeze, 1782, is available under the International Rules of Zoological Nomenclature, and since it is the oldest available name, the correct name of the kidney worm of carnivores is considered to be *Dioctophyma renale* (Goeze, 1782).

If we were to assume that the word "Gigas" as employed by Goeze is available as a specific name under the rules, this name must be applied to all the various forms of nematodes which that author listed under the heading, "Gigas," from (a) to (f). The name "*Renales*" in that case is of lower rank, and therefore, it is employed as a subspecific name and it becomes available under the rules, since, according to Article 11, subspecific and specific names are of the same value.

The specific name *visceralis* which is the next available name, was proposed by Gmelin (1790). On the following page of the same work Gmelin also used the name *renalis* for the same parasite, namely, the kidney worm of carnivores. Therefore, *visceralis* Gmelin, 1790, is a renaming of *Dioctophyma renale* and becomes a synonym.

COMMITTEE ON NOMENCLATURE,
PAUL D. HARWOOD, *Chairman*
B. G. CHITWOOD
ALLEN MCINTOSH

AMERICAN SOCIETY OF PARASITOLOGISTS

ANNOUNCEMENT OF PLACE OF SEVENTEENTH ANNUAL MEETING

Acting under authority voted at the sixteenth annual business meeting in Philadelphia, the Council has decided that the seventeenth annual meeting of the American Society of Parasitologists shall be held in Dallas, Texas, in conjunction with the meeting of the American Association for the Advancement of Science. Sessions for the presentation of papers will be scheduled for Monday, Tuesday, and Wednesday, December 29, 30 and 31, 1941.

O. R. MCCOY, *Secretary*